AD NUMBER

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AUTHORITY

Space Systems Division ltr, 25 Mar 1965

Report Number
TOR-169(3305)-1

(1) Scale 1

HYPERSONIC WIND TUNNEL FACILITIES IN THE UNITED STATES

MARCH 1963

Prepared by

F. A Vicente and Nancy S. Foy
Fluid Mechanics Department

AEROSPACE CORPORATION
El Segundo, California

Contract No. AF 04(695)-169

Prepared for

COMMANDER SPACE SYSTEMS DIVISION
UNITED STATES AIR FORCE
Inglewood, California

Report Number
TOR-1691(3305)-1

(4) NA
(5) 17505
(6)

HYPERSONIC WIND TUNNEL FACILITIES IN THE UNITED STATES,

(1) NA
(8) NA
(9) NA
(12) IV
(13) NA
(14) NA
(17) NA
(18) NA
(19) NA
(20) ii
(21) NA

(1) March 1963

~~Prepared~~ (10) by

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IN

THE UNITED STATES

Prepared by _____
F. A. Vicente
Fluid Mechanics Department
Engineering Division
Aerospace Corporation

Prepared by _____
Nancy S. Foy
Fluid Mechanics Department
Engineering Division
Aerospace Corporation

Approved _____
Barry Moss, Head
Fluid Mechanics Department
Engineering Division
Aerospace Corporation

Approved _____
W. P. Targoff, Associate Director
Spacecraft Engineering Subdivision
Engineering Division
Aerospace Corporation

FOREWORD

This report will be amended as required to reflect changes in operational status or capabilities of the various hypersonic wind tunnel facilities. Published copies of the changes will be mailed to all agencies and personnel on the original distribution list. A revision sheet has been included herein to enable users to record changes as they are incorporated within the original report.

REVISION SUMMARY

REV. CODE	REV. DATE	REVISION DETAILS	REVISION ACTION	REV. CCN	REVISION APPROVAL(S)

AEROSPACE FORM 3024

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CONTENTS (continued)

CONTENTS (continued)

405493

HYPERSONIC WIND TUNNEL FACILITIES IN THE UNITED STATES

This report presents a compilation of hypersonic wind tunnel facility data, with particular attention given to operating characteristics of the major hypersonic wind tunnels in the United States. The information has been compiled to assist personnel who must evaluate and select facilities for hypersonic wind tunnel test programs.

A brief description is given for each facility. These descriptions include information regarding responsible personnel; nozzle and test section; instrumentation; operational status, where such information is pertinent; data reduction method, whenever this has been available; running times; and particular test capabilities of each facility.

An envelope of Reynolds number versus Mach number was drawn for each facility, using a uniform scale. Since envelopes of stagnation conditions were available in most cases, these also have been drawn on a uniform scale. In these graphs Mach number and Reynolds number represent free stream conditions, and stagnation pressure, temperature and enthalpy refer to conditions in the stagnation region of the model, except for the few cases where reservoir conditions are specified.

Since all information in this report was plotted using Mach number as a parameter, graphs are included in the introductory section which correlate Mach number and altitude. These are based on the 1962 Revised U.S. Standard Atmosphere, and consider air to be a perfect gas, with $\gamma = 1.4$ and $R = 1716\ ft^2/sec^2\ {}^{o}R$.

Over-all maps of Reynolds number, stagnation pressure and stagnation temperature are provided to permit immediate determination that a wind tunnel test can be performed under specific environmental conditions. Once this possibility has been established, specific facility performance

envelopes can be examined to determine which facilities have the capability required for the desired test. It should be emphasized here, however, that the purpose of this report is to serve only as a preliminary guide in facility selection. In every case, the individual facility should be contacted to determine tunnel availability, schedules and cost, and to verify operational status and tunnel operating parameters.

The facilities appear within the report in alphabetical order. However, they are indexed according to type of tunnel (i.e. continuous, hotshot, blowdown or shock) and type of organizational management (i.e. government, industrial, university and non-profit corporations).

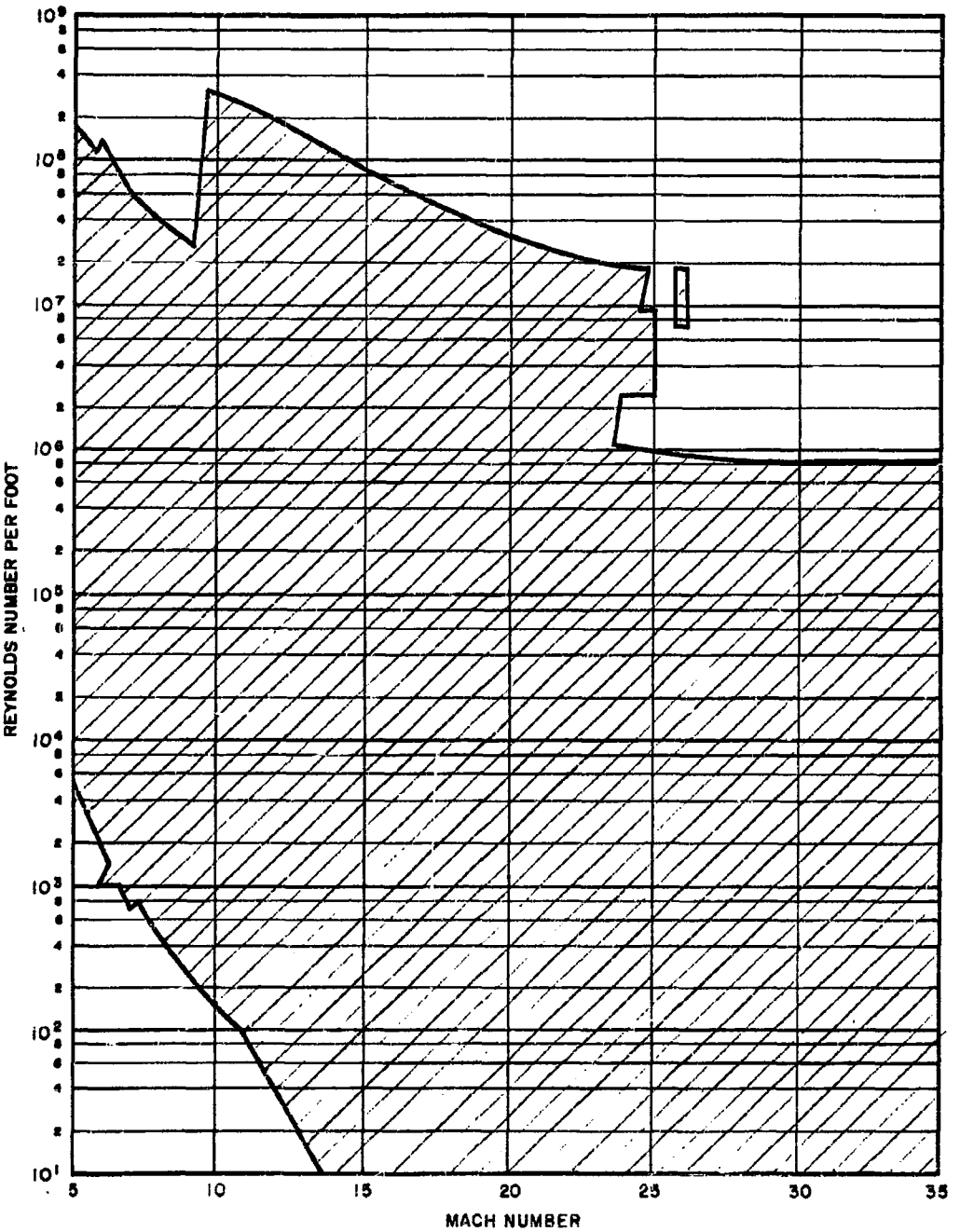
A preliminary report was compiled and published in rough draft form in November 1962. This report included data submitted by the various facilities, as well as information which was available in the literature. Each section was sent to the facility manager. These sections were corrected, updated and returned by 37 of the 39 facilities. This final report incorporates all changes and corrections forwarded by the facility managers from November 1962 to March 1963.

It is hoped that new data will be sent to Aerospace as it becomes available, so that this report may be updated periodically. Permanent files will be maintained within the Fluid Mechanics Department of the Engineering Division of Aerospace Corporation. These files presently contain the material referenced within this report, and are available to interested personnel.

The authors particularly appreciate the assistance of the many facility personnel who have taken extra time and trouble to assure that this report will include the most accurate and timely information available.

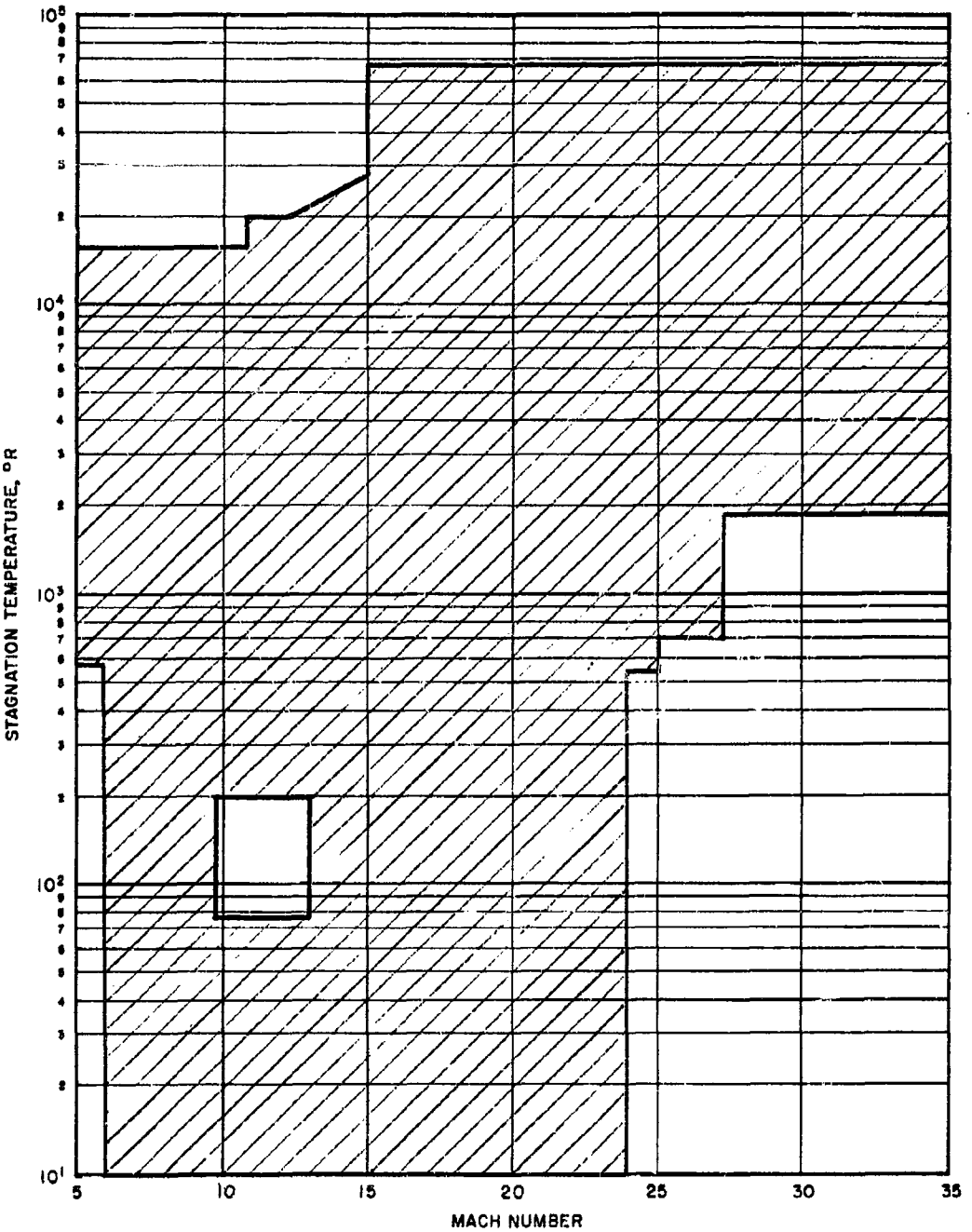
OVERALL PERFORMANCE MAP OF WIND TUNNEL FACILITIES

CURRENTLY OPERATIONAL OR UNDER CONSTRUCTION



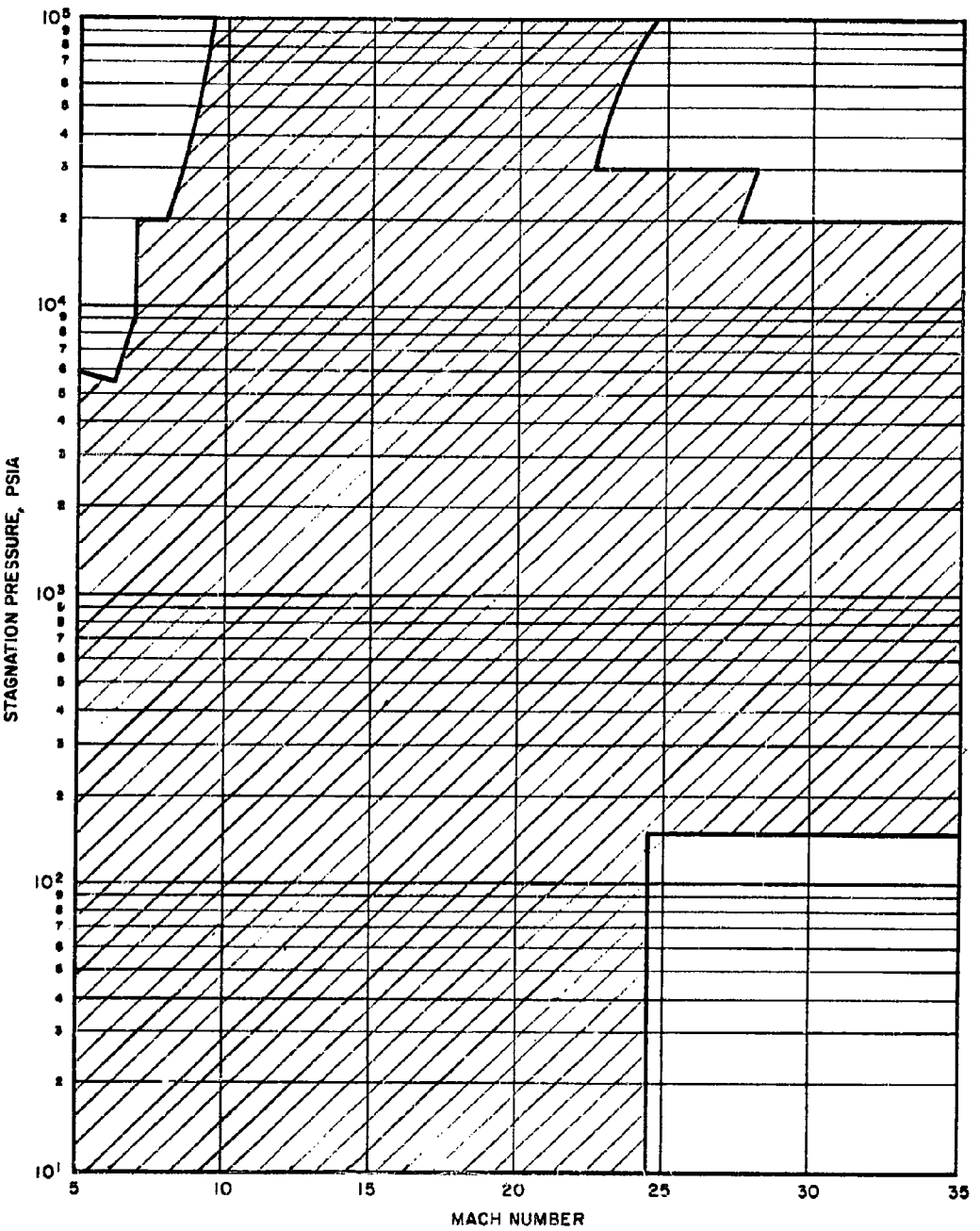
OVERALL PERFORMANCE MAP OF WIND TUNNEL FACILITIES

CURRENTLY OPERATIONAL OR UNDER CONSTRUCTION



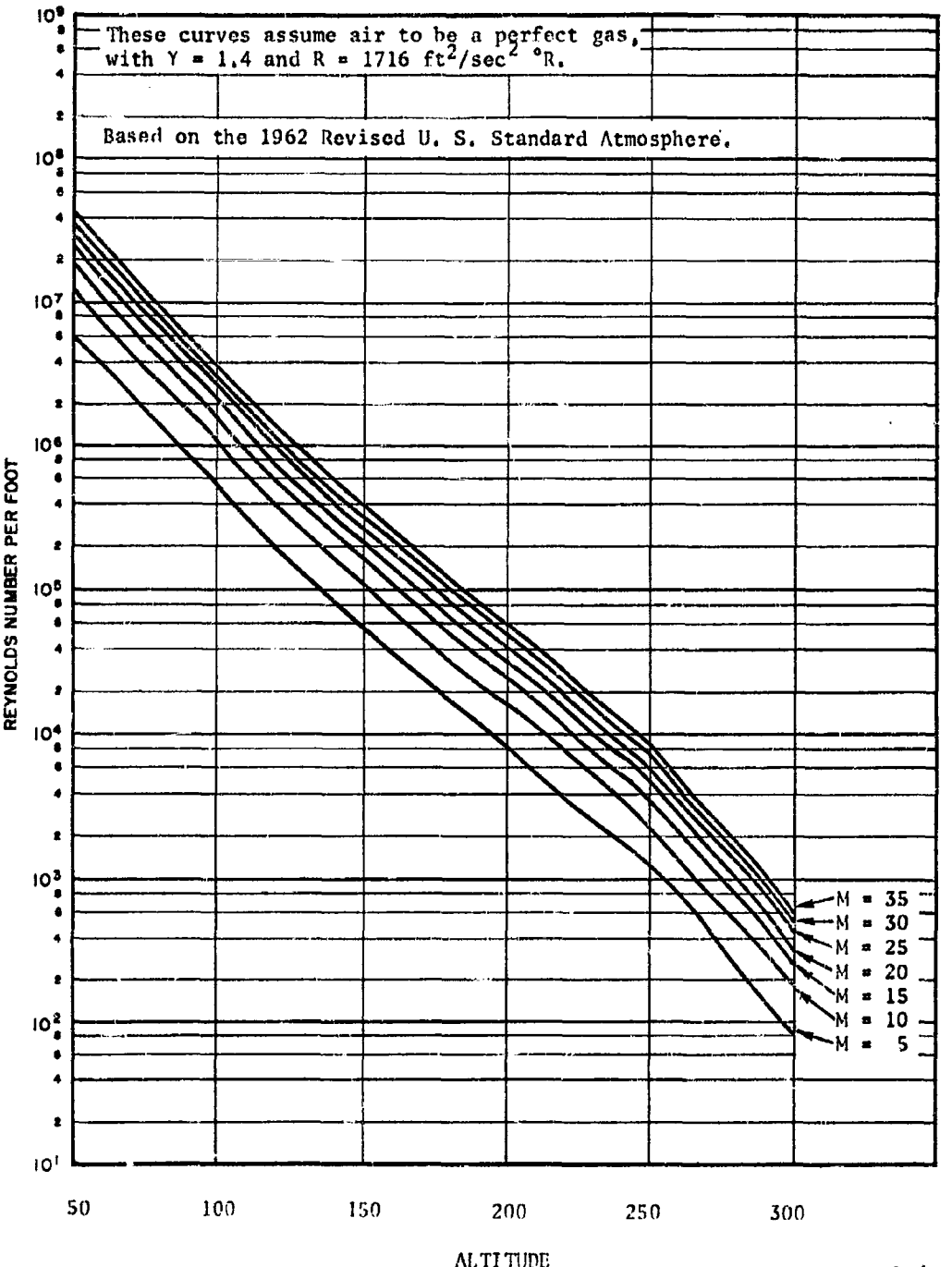
OVERALL PERFORMANCE MAP OF WIND TUNNEL FACILITIES

CURRENTLY OPERATIONAL OR UNDER CONSTRUCTION

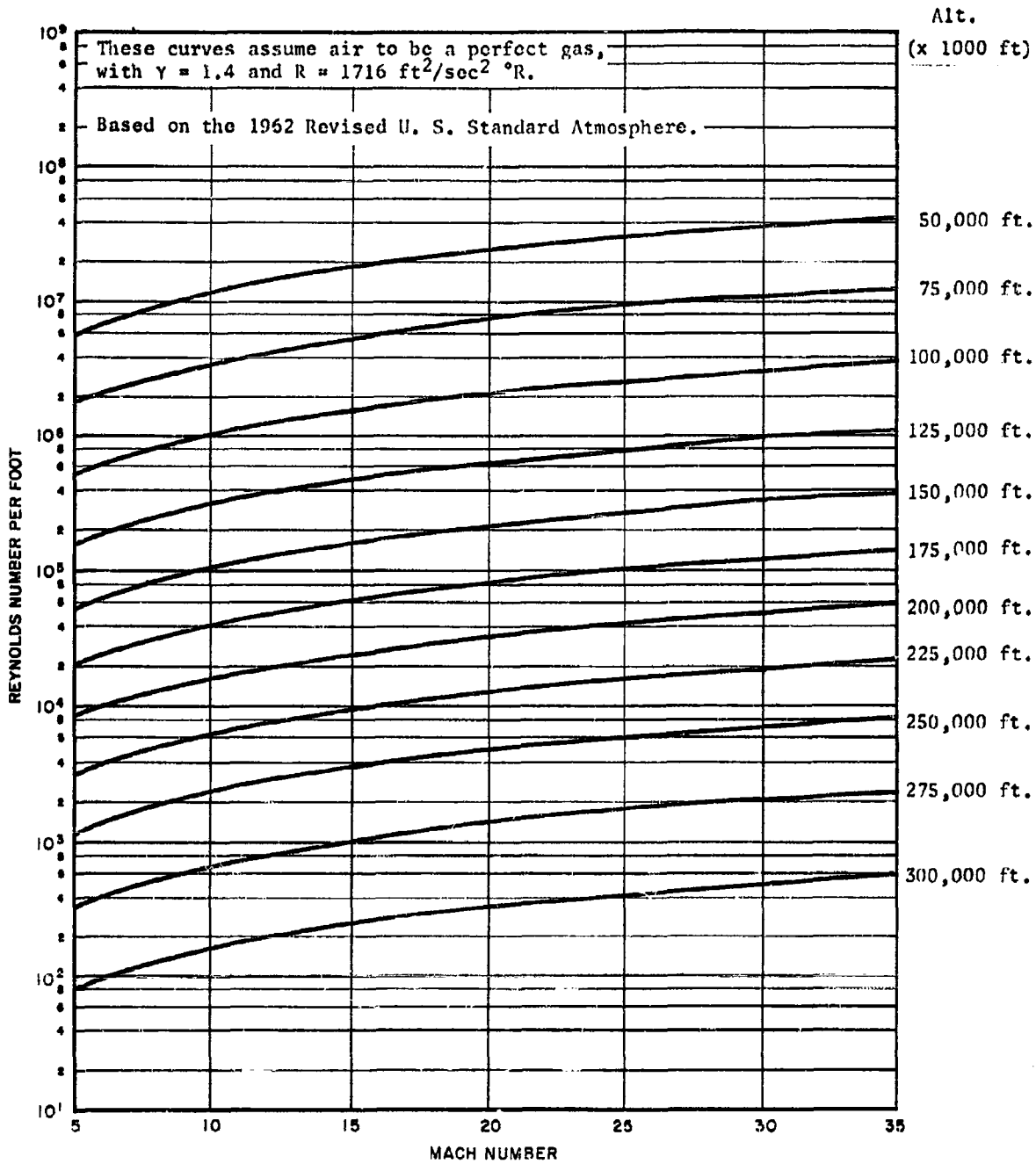


REYNOLDS NUMBER PER FOOT

AS A FUNCTION OF ALTITUDE



REYNOLDS NUMBER PER FOOT
AS A FUNCTION OF FREE STREAM MACH NUMBER



REYNOLDS NUMBER-MACH NUMBER-ALTITUDE CHART

Altitude	M = 5	M = 10	M = 15	M = 20	M = 25	M = 30	M = 35
50,000 ft.	5.991+6	1.198+7	1.797+7	2.396+7	2.995+7	3.595+7	4.193+7
75,000 ft.	1.812+6	3.624+6	5.436+6	7.248+6	9.059+6	1.087+7	1.268+7
100,000 ft.	5.268+5	1.053+6	1.579+6	2.107+6	2.634+6	3.161+6	3.687+6
125,000 ft.	1.574+5	3.146+5	4.719+5	6.293+5	7.865+5	9.438+5	1.101+6
150,000 ft.	5.378+4	1.075+5	1.613+5	2.151+5	2.688+5	3.226+5	3.764+5
175,000 ft.	2.016+4	4.033+4	6.049+4	8.065+4	1.008+5	1.210+5	1.411+5
200,000 ft.	8.226+3	1.646+4	2.468+4	3.291+4	4.114+4	4.937+4	5.759+4
225,000 ft.	3.185+3	6.370+3	9.557+3	1.274+4	1.593+4	1.911+4	2.229+4
250,000 ft.	1.189+3	2.379+3	3.568+3	4.756+3	5.946+3	7.135+3	8.325+3
275,000 ft.	3.415+2	6.830+2	1.025+3	1.366+3	1.708+3	2.050+3	2.390+3
300,000 ft.	8.193+1	1.640+2	2.459+2	3.278+2	4.097+2	4.917+2	5.736+2

$+7 = \times 10^{7}$

These figures assume air to be a perfect gas, with $\gamma = 1.4$ and $R = 1716\ ft^2/sec^2\ {}^{o}R$.

Based on the 1962 Revised U. S. Standard Atmosphere.

Name of Facility

Aeronautical Systems Division
Air Force Systems Command, USAF
Wright-Patterson Air Force Base, Ohio

Person Responsible

Mr. J. P. Doyle, Jr., ASTEA
Chief, Aerodynamics Division
Directorate of Engineering Test
Deputy for Test and Support

Type

A) The ASD Electro-Gasdynamics Facility, which will be operational in 1963, is of the semi-free jet type.

B) The High Temperature Hypersonic Gasdynamics Facility (HTF) is of the free jet type, using a pebble-bed heater capable of heating the test gas to 4750°R stagnation temperature. The facility is presently operational.

Nozzle and Test Section

A) The Electro-Gasdynamics Facility will have three straight conical nozzles, with test section diameters of 7, 19 and 24 inches, a sting type model support and injection system, and will accommodate a model approximately one half the nozzle exit diameter.

B) The High Temperature Hypersonic Gasdynamics Facility has M = 8, 10, 12 and 14 contoured axisymmetric nozzles, with a 24 inch exit diameter. The test section is a free jet surrounded by a plenum tank of the same pressure as the static pressure at the nozzle exit. The model support has the capability of injecting two models alternately in the flow and can be pitched through $\pm$ 45°. The maximum model frontal area permissible is 40 square inches at Mach 8, and 20 square inches at Mach 10, 12 and 14.

Instrumentation and Test Capabilities

A) The Electro-Gasdynamics Facility will have a Millisadic data collection system, with mass spectrometer and various pressure and enthalpy probes available.

B) The HTF has a Millisadic data collection system, optical spectrograph, pressure and temperature instrumentation and optical flow visualization apparatus.

Running Times

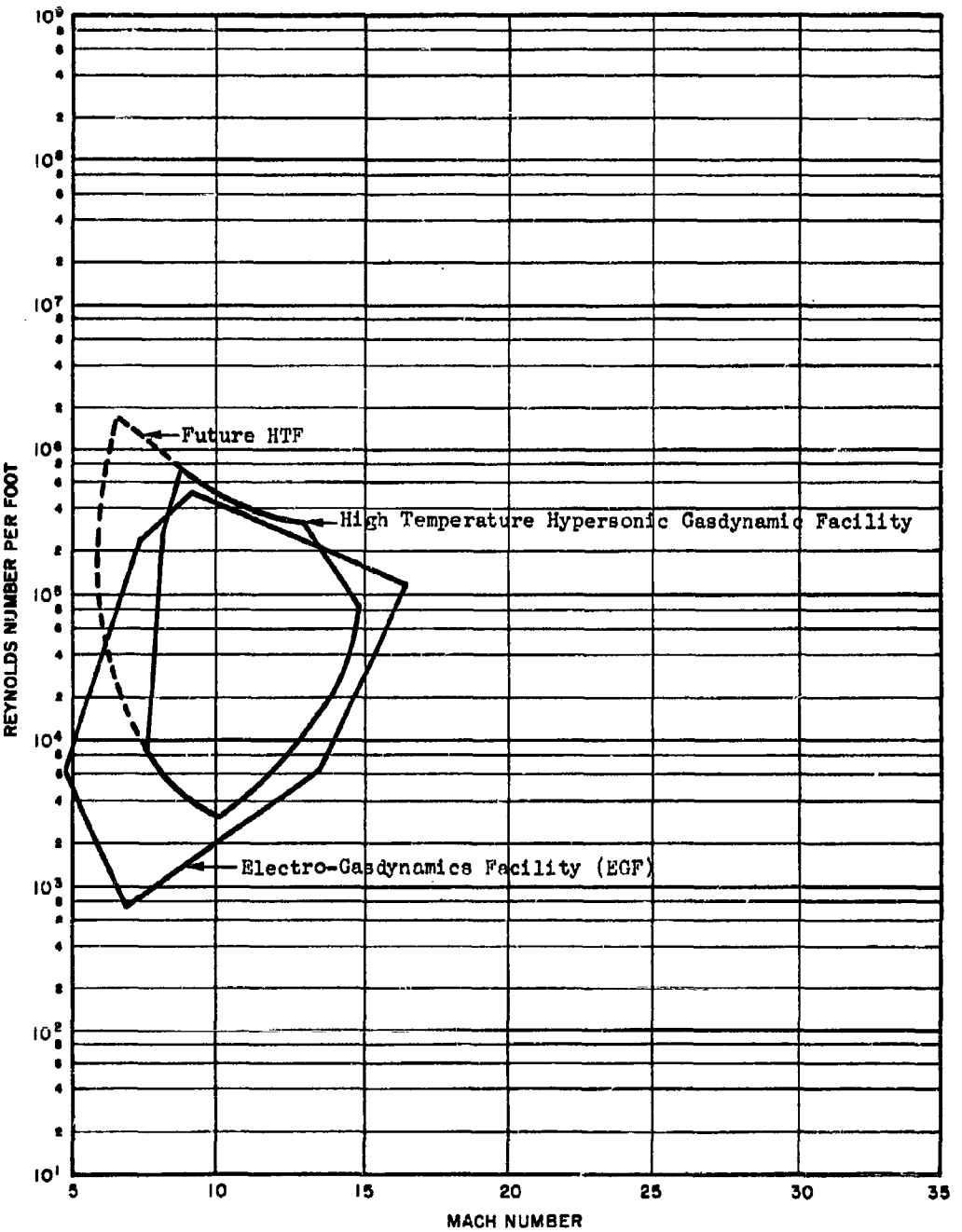
A) Electro-Gasdynamics Facility - 3 to 10 minutes.

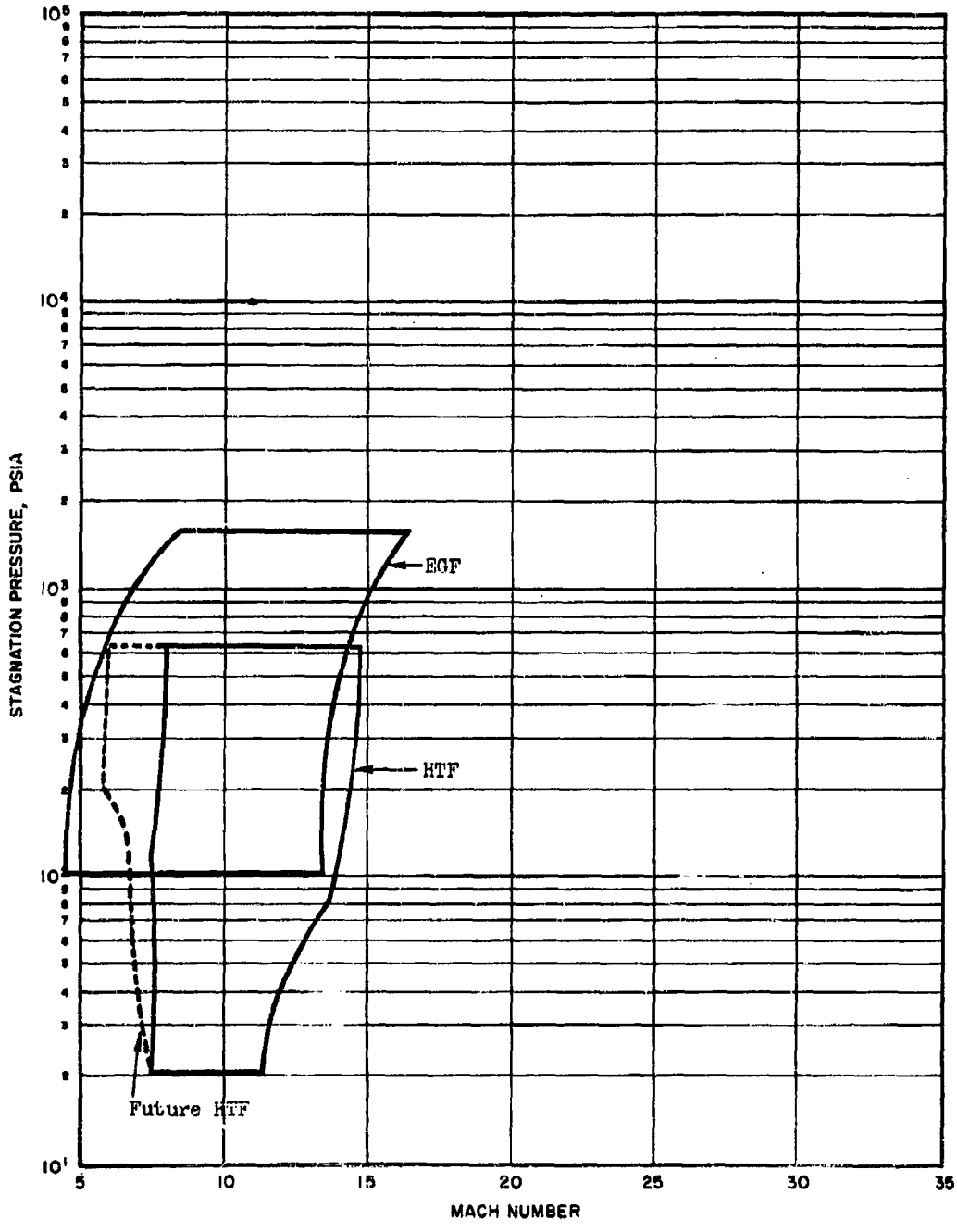
B) HTF - 50 to 800 seconds, depending on Mach number and stagnation pressure.

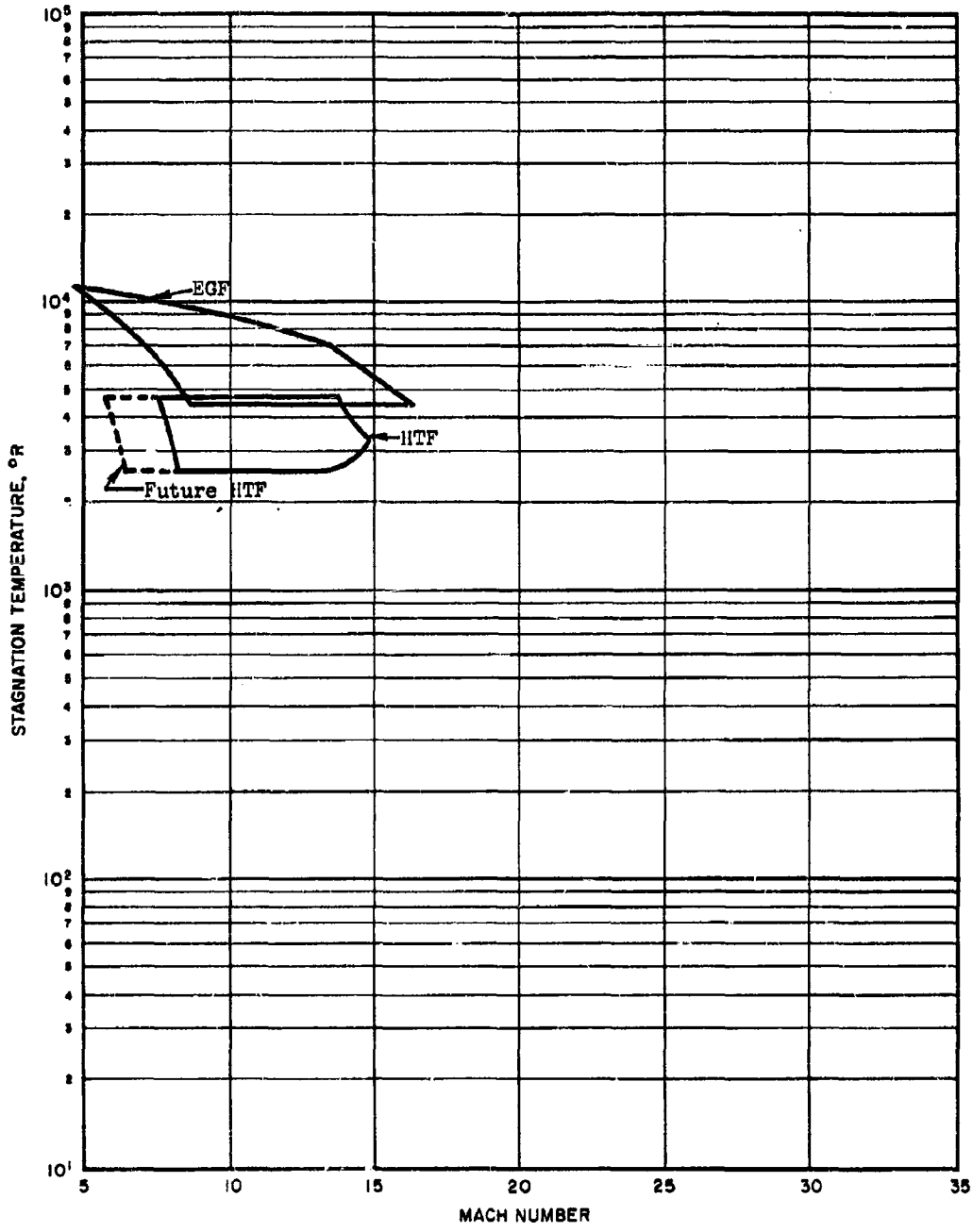
References

1. Letter, J. P. Doyle, Jr. to F. A. Vicente, subject: "Hypersonic Wind Tunnel Survey," with attachments, dated 5 September 1962.

2. Letter, J. P. Doyle, Jr. to N. S. Foy, subject: "Operating Parameters of the ASD Hypersonic Gasdynamics Facilities," with attachments, dated 23 November 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Future HTF
High Temperature Hypersonic Gasdynamic Facility
Electro-Gasdynamics Facility (EGF)


STAGNATION PRESSURE, PSIA
MACH NUMBER
EGF
HTF
Future HTF
5
10
15
20
25
30
35


STAGNATION TEMPERATURE, °R
MACH NUMBER
EGF
HTF
Future HTF
10⁵
10⁴
10³
10²
10¹
5
10
15
20
25
30
35

Name of Facility

Hypersonic Shock Tunnel
Aerospace Corporation
2400 E. El Segundo Boulevard
El Segundo, California

Person Responsible

Mr. Robert L. Varwig

Type

The Aerospace facility is a helium driven shock tunnel. At present it uses a cold helium driver. The combustion heated driver, using a mixture of hydrogen-oxygen and helium, is presently in the shakedown stage.

Nozzle and Test Section

The Hypersonic Shock Tunnel has a conical nozzle and a test section diameter of 66 inches. It can accommodate a model two feet in diameter.

Instrumentation and Test Capabilities

Measurements have been made in this facility of pressure, heat transfer and aerodynamic forces.

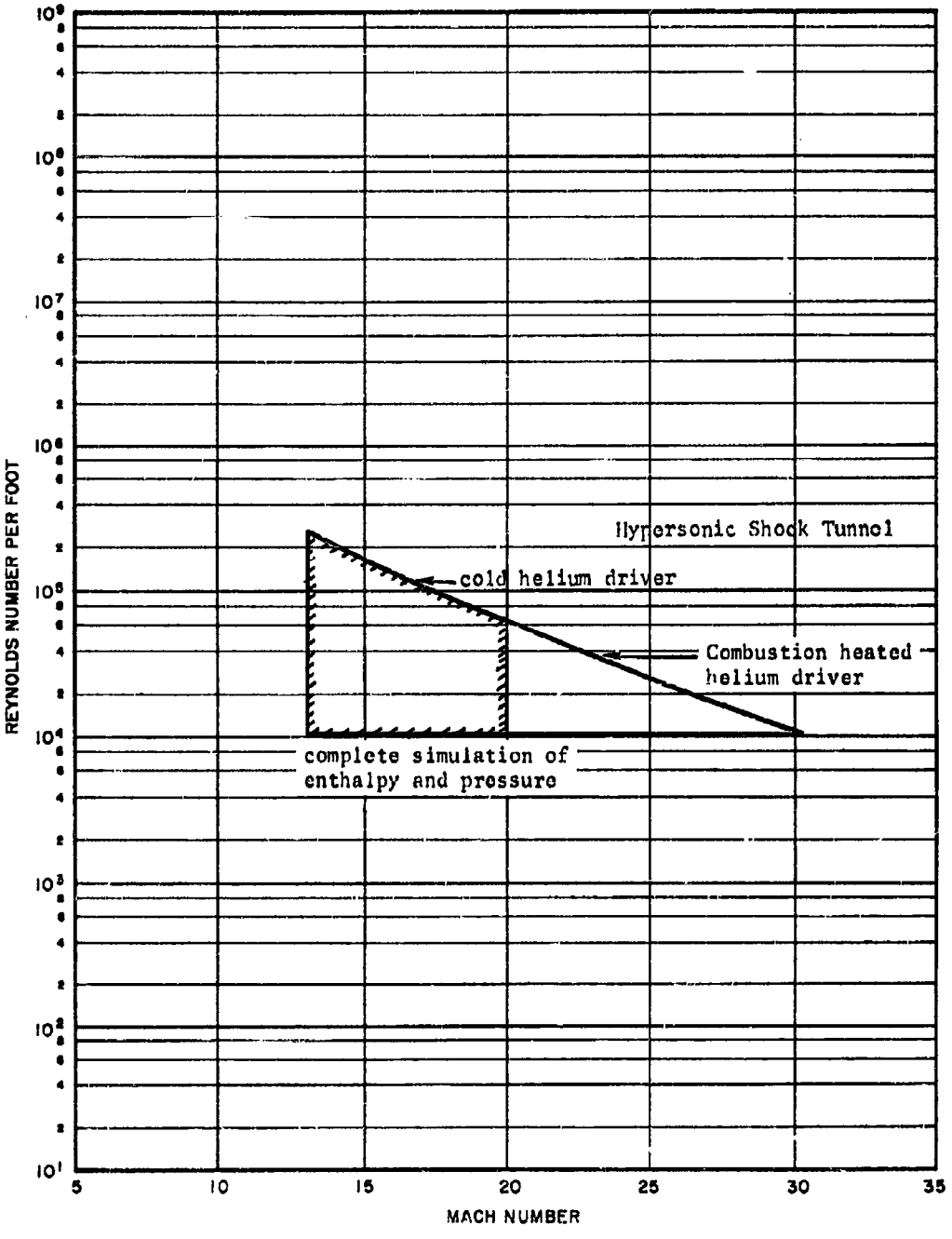
Running Time

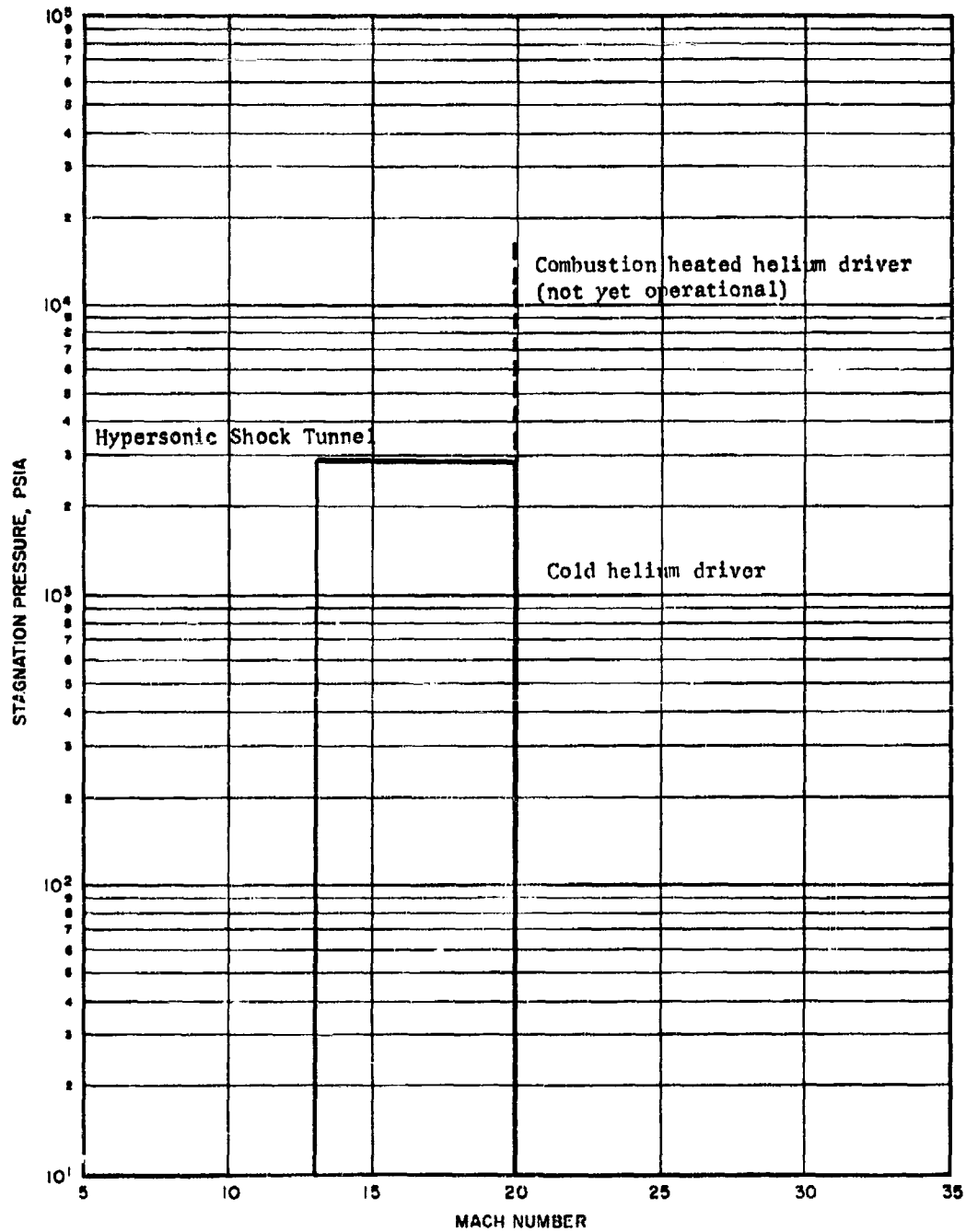
Running times in the Aerospace facility are on the order of 6 milliseconds.

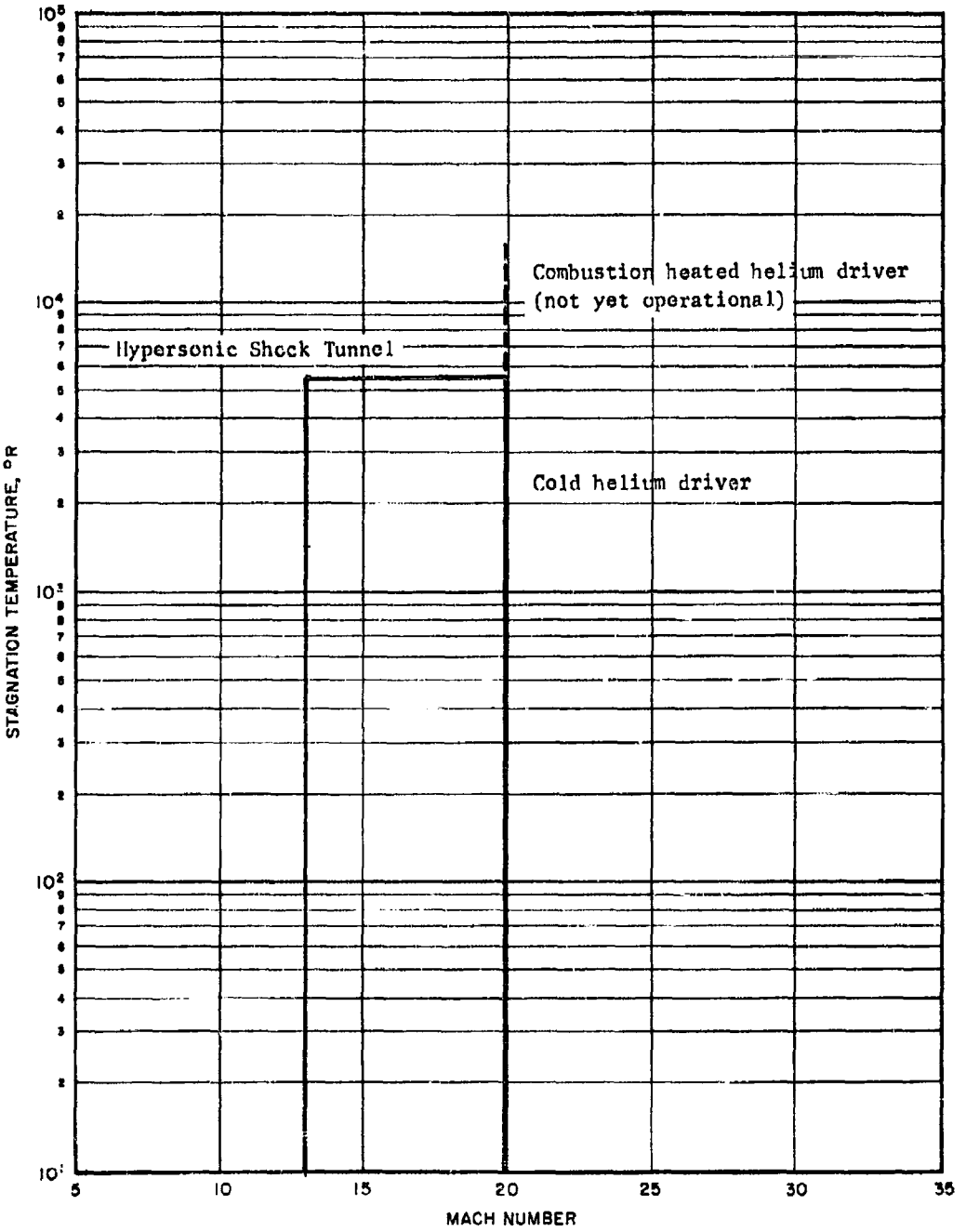
References

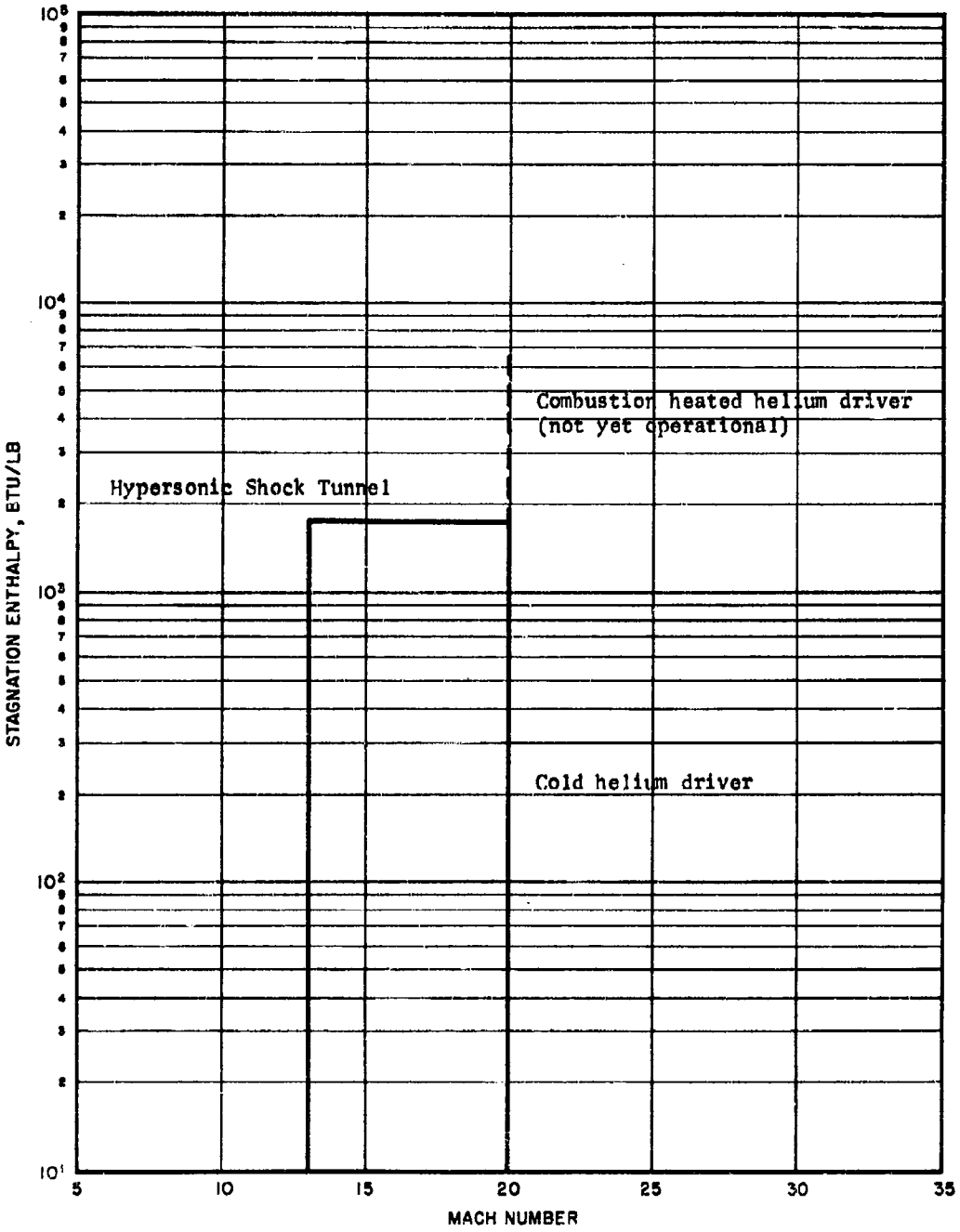
1. "Reynolds Number vs Mach Number", graph, undated.

2. Interview with R. L. Varwig, 8 October 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hypersonic Shock Tunnel
cold helium driver
Combustion heated helium driver
complete simulation of enthalpy and pressure


Combustion heated helium driver
(not yet operational)
Hypersonic Shock Tunnel
Cold helium driver
STAGNATION PRESSURE, PSIA
MACH NUMBER
5
10
15
20
25
30
35


Combustion heated helium driver
(not yet operational)
Hypersonic Shock Tunnel
Cold helium driver
STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35


STAGNATION ENTHALPY, ETU/LB
MACH NUMBER
Combustion heated helium driver
(not yet operational)
Hypersonic Shock Tunnel
Cold helium driver

Name of Facility

Hypersonic Wind Tunnel
Armour Research Foundation of Illinois Institute of Technology
10 West 35th Street
Chicago 16, Illinois

Person Responsible

Dr. William J. Christian
Manager, Heat and Mass Transfer Section

Type

The Armour hypersonic wind tunnel is of the intermittent blowdown type.

Nozzle and Test Section

The flow is expanded through a nozzle contoured to provide a uniform Mach 6.5 jet. The test section is of the open jet type, 3 inches in diameter and 6 inches in length.

Instrumentation and Test Capabilities

Visual observation of the flow is provided by a Schlieren; strip recorders provide continuous monitoring of temperature, and pressure is measured by manometer banks.

Running Time

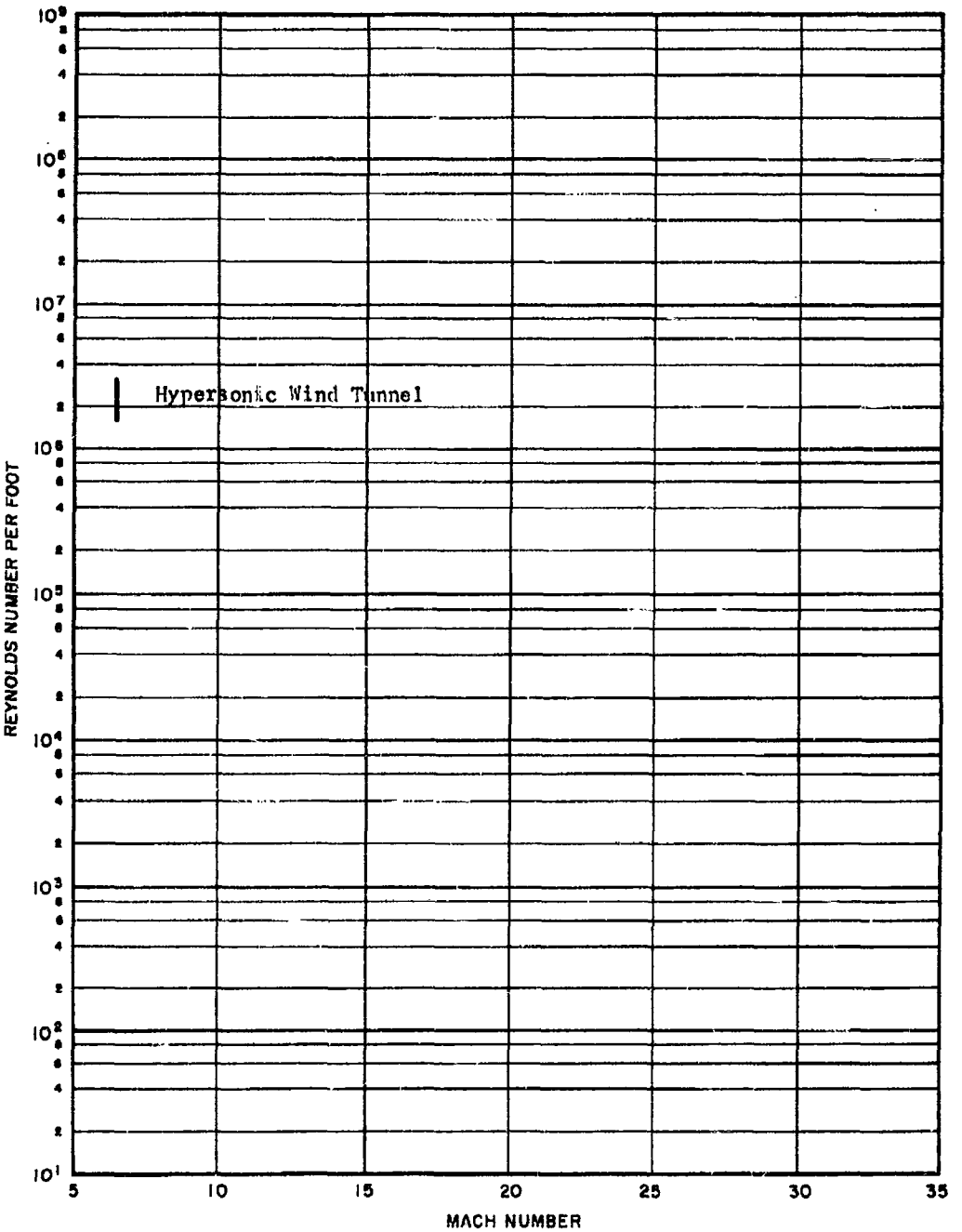
At Mach 6.5, P_o = 180 psia, T_o = 600°F, the tunnel run time is on the order of three minutes. At higher Mach numbers, the run times will be greater.

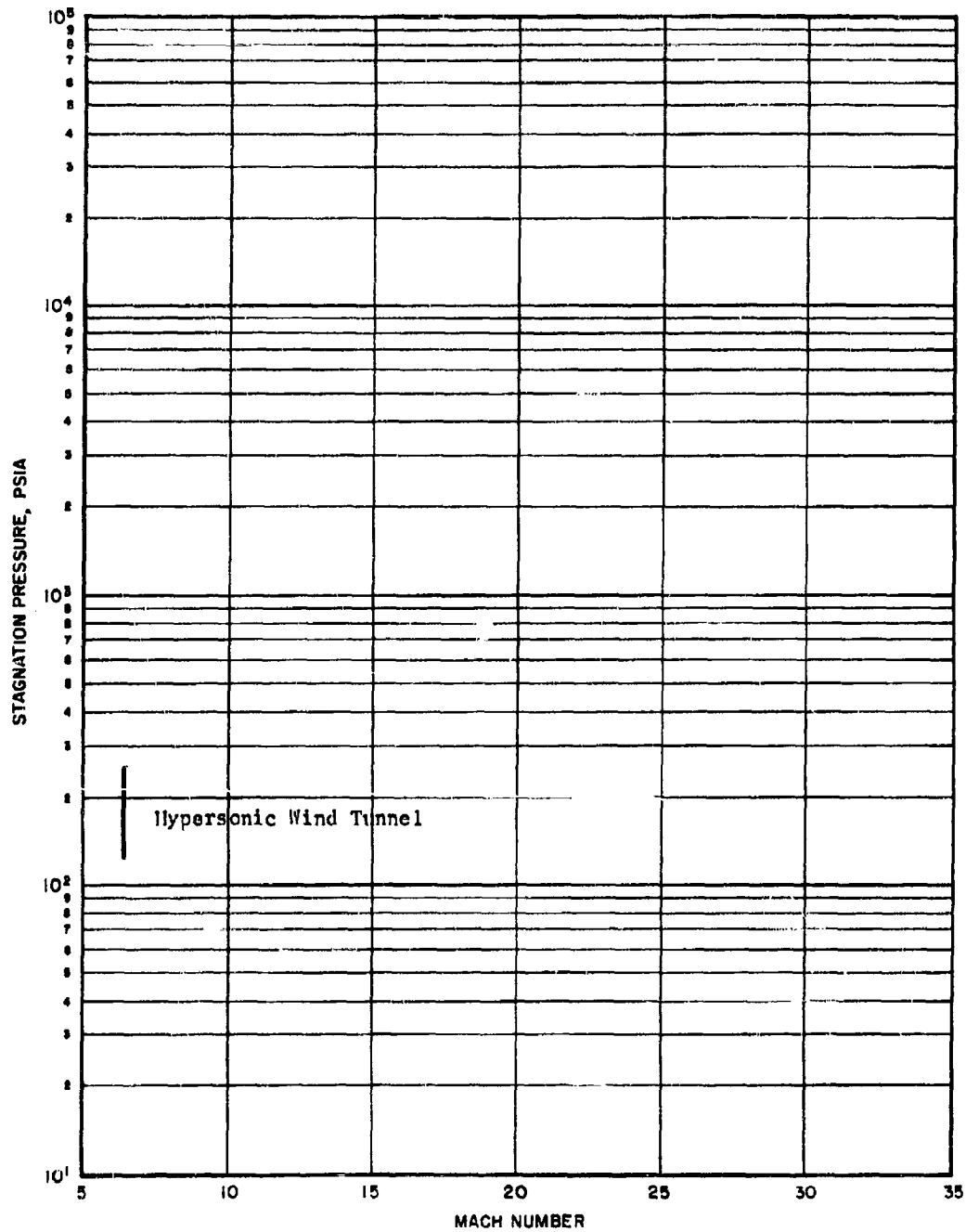
Remarks

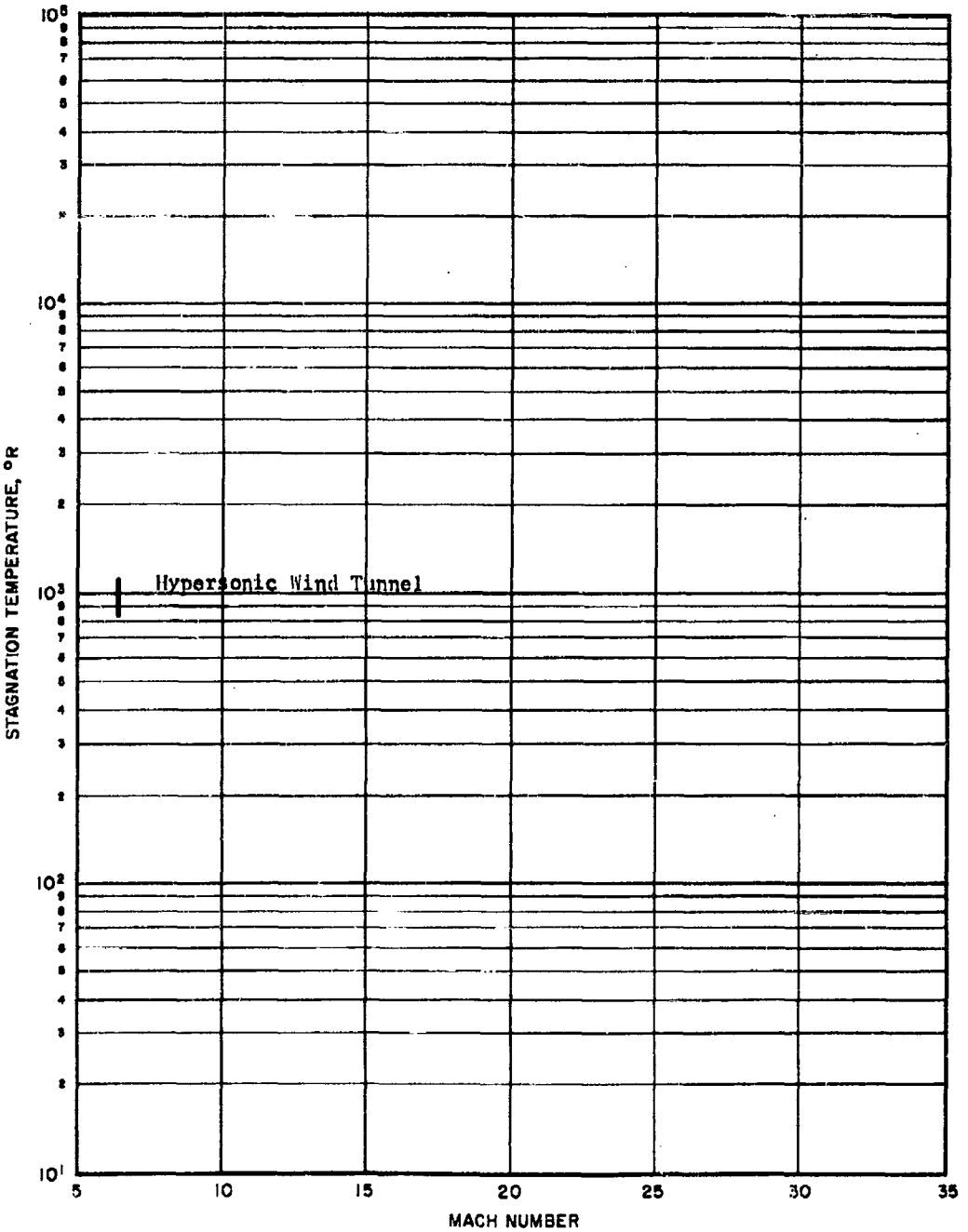
This facility is still in the development process, and has been operated only at M = 6.5. Eventual capabilities will include a Mach number range of 5 to 10, stagnation pressures of 2100 psia, stagnation temperatures to 1460°R and a Reynolds number range from 10^6 to 10^7 per foot.

References

1. "Space Exploration Capabilities of Armour Research Foundation," brochure, dated July 1962.
2. Letter, Dr. W. J. Christian to N. S. Foy, dated 5 February 1963.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hypersonic Wind Tunnel
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
Hypersonic Wind Tunnel


STAGNATION TEMPERATURE, °R
MACH NUMBER
Hypersonic Wind Tunnel
5
10
15
20
25
30
35

Name of Facility

Von Karman Gas Dynamics Facility
Arnold Engineering and Development Center
Tullahoma, Tennessee

Person Responsible

J. Lukasiewicz
R. Jackson

Type

Two types of tunnels are operational at this facility. They are: the continuous hypersonic wind tunnels (Legs B and C and the Low Density Tunnel) and the arc driven Hotshot Tunnels (Legs Hotshot-2 and F). A 100 foot pilot ballistic range is now in operation, in which wake studies are being conducted.

Nozzle and Test Section

All tunnels are perfect gas facilities except for the low density tunnel.

A) Tunnel B has a contoured M = 8 nozzle and a test section diameter of 50 inches.

B) Tunnel C has a contoured M = 10 nozzle and a test section diameter of 50 inches.

C) Tunnel E-2 is a 12 × 12 inch intermittent hypersonic wind tunnel with a Mach number range of 5 to 8. It has a semiflexible nozzle with fixed, rotating throat blocks.

D) Hotshot 2 has a conical nozzle capable of M = 16 to M = 21 operation, using nitrogen as the test gas. The test section diameter is 50 inches.

E) Tunnel F is similar to Hotshot 2 except that it expands into a 100 inch diameter test section.

F) The low density tunnel uses a 30° total angle conical nozzle and 6 inch exit diameter, which yields a one inch to two inch diameter test core. Real gas experiments are made in this facility, using gases other than air.

Instrumentation and Test Capabilities

At present the tests being conducted in the Hotshots are force, pressure and some heat transfer. Force, pressure and heat transfer tests may be conducted in Tunnels B and C. The Low Density Facility is primarily used in basic research projects, rather than operational types of testing.

Running Times

A) Tunnel B - continuous.

B) Tunnel C - continuous.

C) Tunnel E-2 - in excess of five minutes.

D) Hotshot 2 - on the order of 50 milliseconds.

E) Tunnel F - on the order of 50 milliseconds.

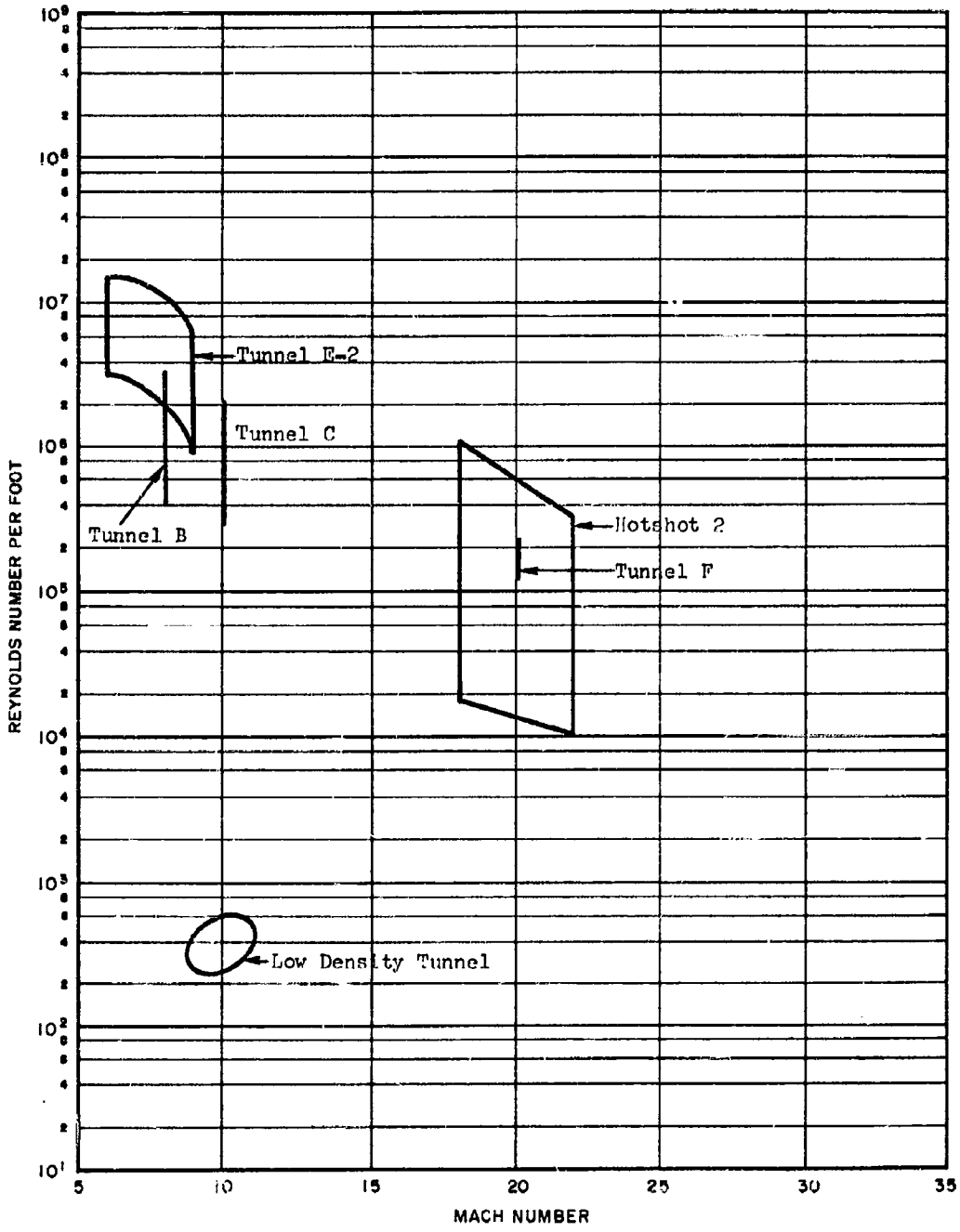
F) Low Density Tunnel - may be operated continuously for several hours.

References

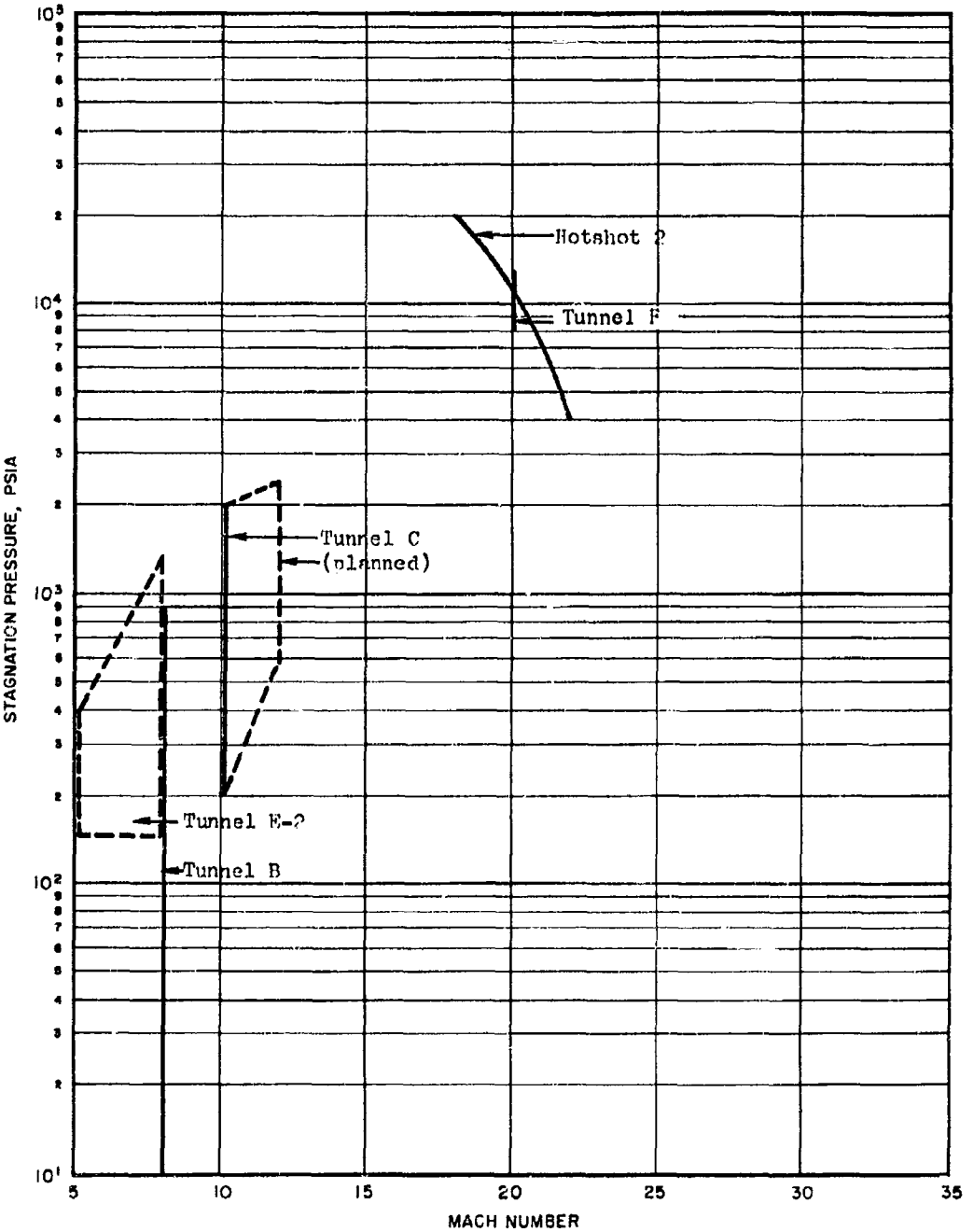
1. "Test Facilities Handbook", Fourth Edition, July 1962. Von Karman Gas Dynamics Facility Publication.

2. Memorandum from S. E. Gilles to F. Vicente, "Discussion with Mr. R. Jackson of the Von Karman Gas Dynamics Facility, Arnold Engineering and Development Center", 62-1941.2-117, dated 11 October 1962.

AEDC
Von Karman Facility

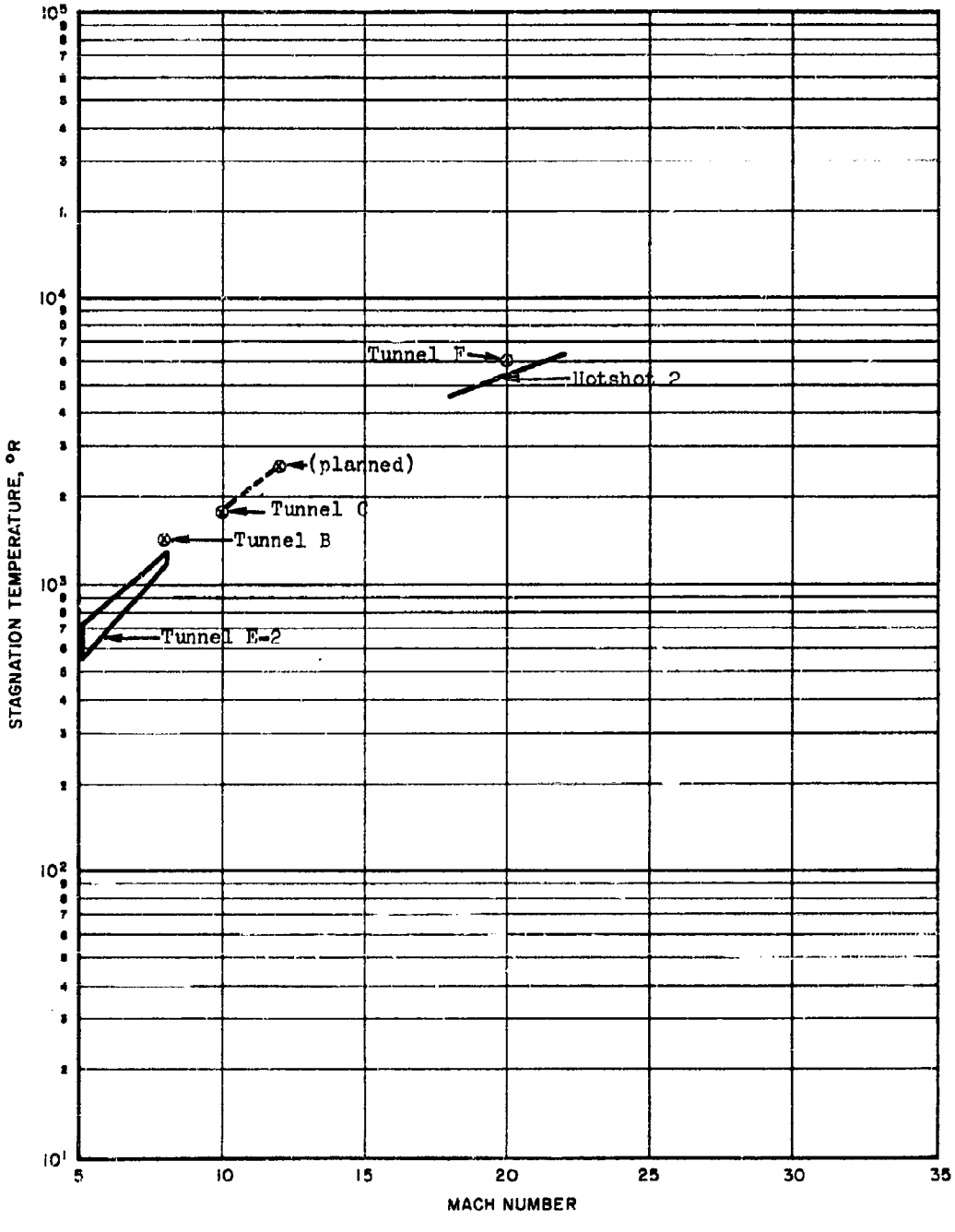


AEDC
Von Karman Facility



AEDC

Von Karman Facility



Name of Facility

AVCO Research and Development
Wilmington, Massachusetts

Person Responsible

Herbert Weisblatt
Assistant Section Chief, Experimental Gasdynamics

Type

A 300 Atmosphere Shock Tunnel, which can be either hydrogen or combustion driven, is in operation. The tunnel has been calibrated at one operational point (see charts) with the hydrogen driver, and is presently undergoing calibration with the combustion driver.

Nozzle and Test Section

The AVCO 300 Atm. Shock Tunnel uses a 7° conical nozzle. At present the nozzle expands to a useful test core diameter of 12.5 inches at M = 11.55.

Instrumentation and Test Capabilities

Pressure and heat transfer tests may be run in the 300 Atm. Shock Tunnel at M = 11.55. At present a strain gage force balance is being developed.

Running Time

The driver sphere technique of tunnel operation developed at AVCO-RAD is currently being used with running times of 4 milliseconds.

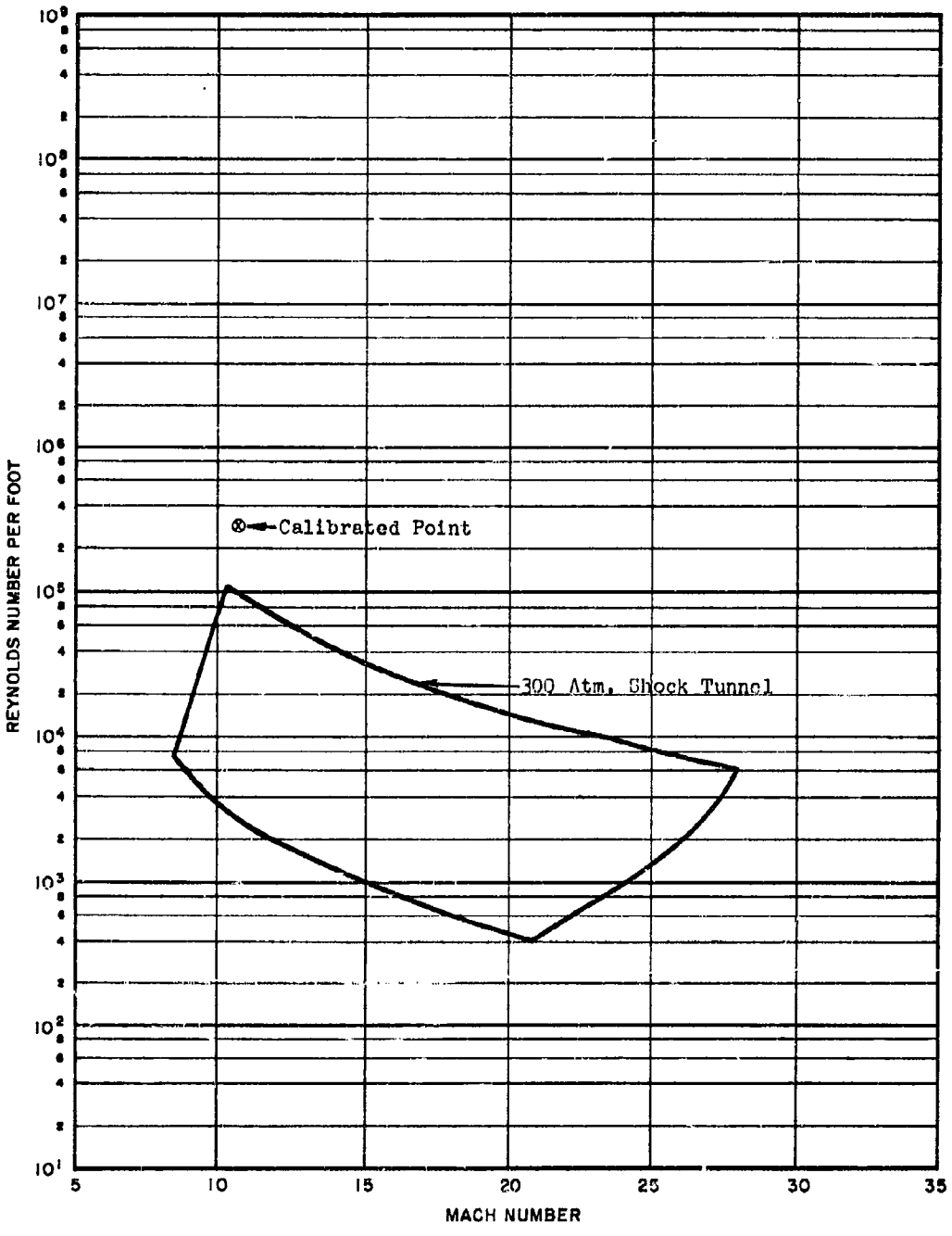
References

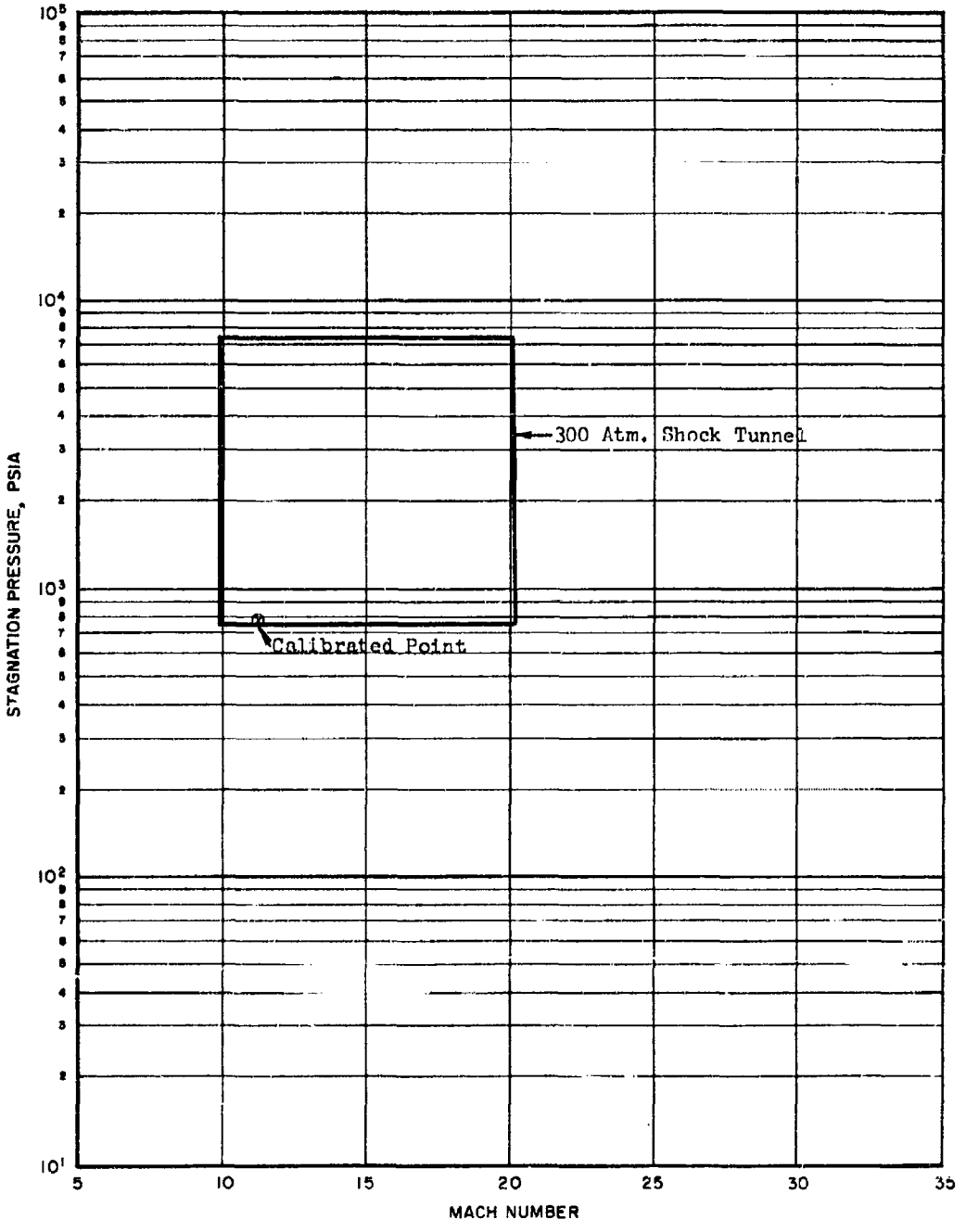
1. "Calibration of 300 Atm Shock Tunnel", by H. Weisblatt, AVCO-RAD TR-62-42.

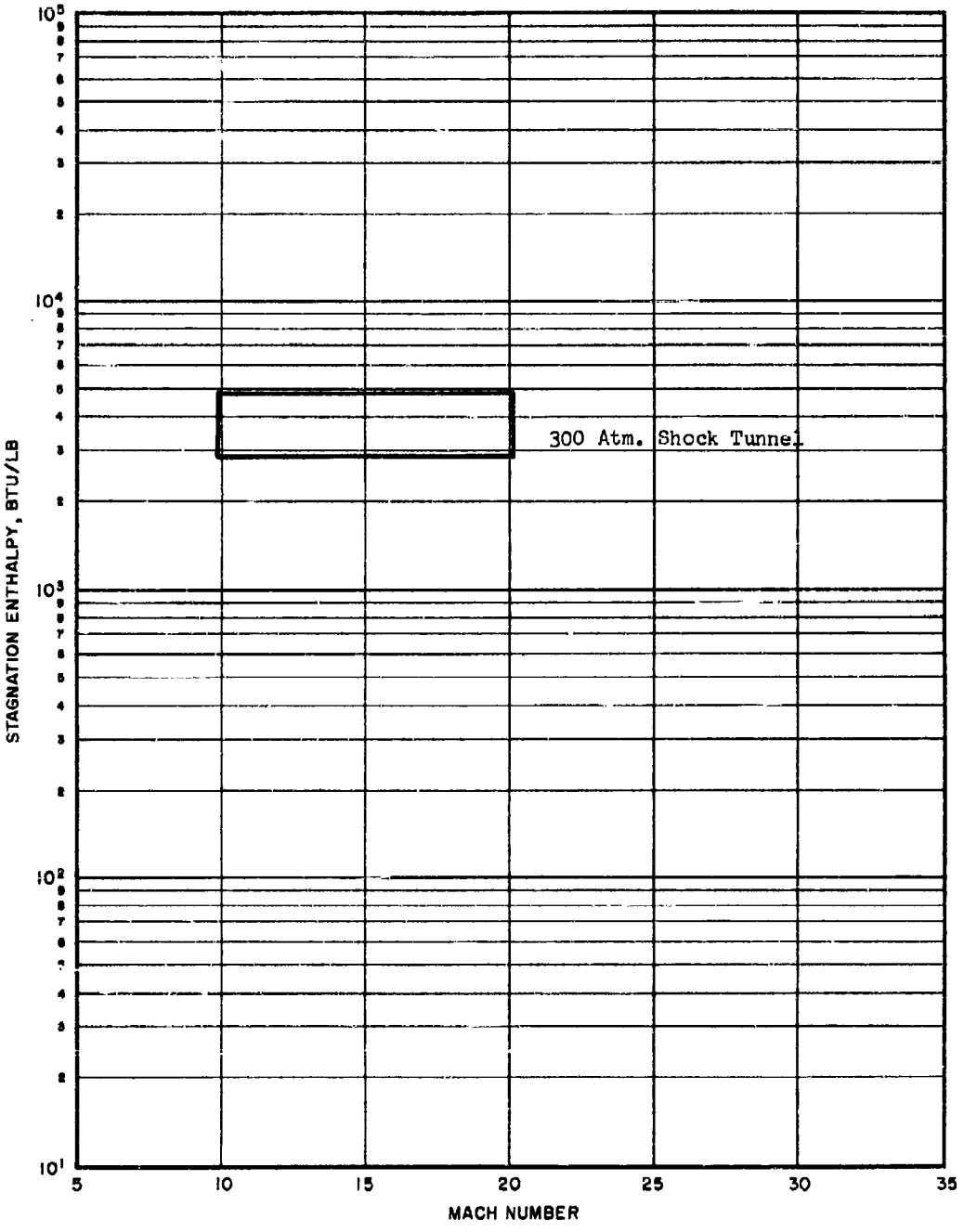
2. "Experimental Technique for Tailored Operation of a Combustion Driven Shock Tunnel", by H. Weisblatt and R. F. Flagg, AVCO-RAD-TM-61-17.

3. "Development of Very High Enthalpy Shock Tunnels with Extended Steady State Test Times", by B. D. Henshall, R. N. Teng and A. P. Wood, AVCO-RAD-TR-62-16.

4. Letter, H. Weisblatt to N. S. Foy, with enclosure, dated 21 December 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
⊗←Calibrated Point
300 Atm. Shock Tunnel
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
300 Atm. Shock Tunnel
Calibrated Point
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
300 Atm. Shock Tunnel
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35

Name of Facility

Aberdeen Wind Tunnel No. 4
Ballistic Research Laboratory
Aberdeen Proving Ground, Maryland

Person Responsible

Robert H. Krieger, Supersonic Wind Tunnel Branch

Type

Aberdeen Wind Tunnel No. 4 is a continuous free-jet type facility.

Nozzle and Test Section

Tunnel No. 4 has three axi-symmetric, water-cooled nozzles, M = 6, 7.5 and 9.2. At M = 9.2 the tunnel has a 13 inch diameter test core, and at M = 6 and 7.5 the test core is 12 inches in diameter. This facility can accommodate a model up to 30 inches long and 4 inches in diameter. The test section is a plenum box, 9 feet high, 7 feet wide and 6 feet long.

Instrumentation and Test Capabilities

This facility has ten data channels for measuring temperature, pressure and force. Data reduction is available through the computing laboratory of the Ballistic Research Laboratories.

Running Time

Wind Tunnel No. 4 - continuous.

References

1. "National Wind Tunnel Summary," NASA Report, dated July 1961.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States," Boeing Report No. D2-5785, dated April 1960.

3. "Wind Tunnel Testing Facilities at the Ballistic Research Laboratories," BRL Memo Report No. 1292, dated July 1960.

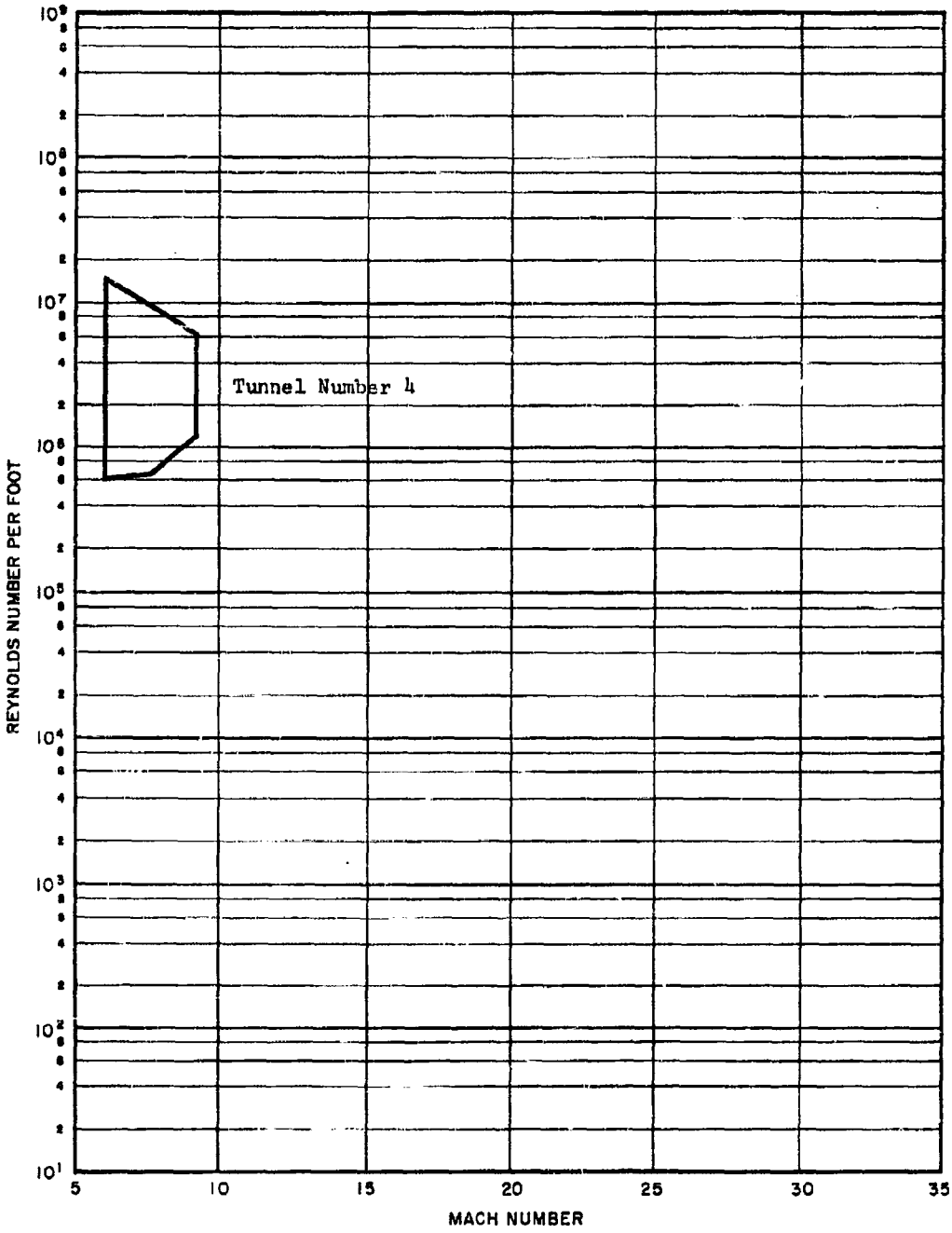
4. "Ballistic Research Laboratories New Hypersonic Tunnel," BRL Report No. 1076, dated January 1960.

5. "The Design and Construction of the Ballistic Research Laboratories Hypersonic Wind Tunnel," preprint of paper presented at AGARD-STA meeting at Marscilles, France, September 1959.

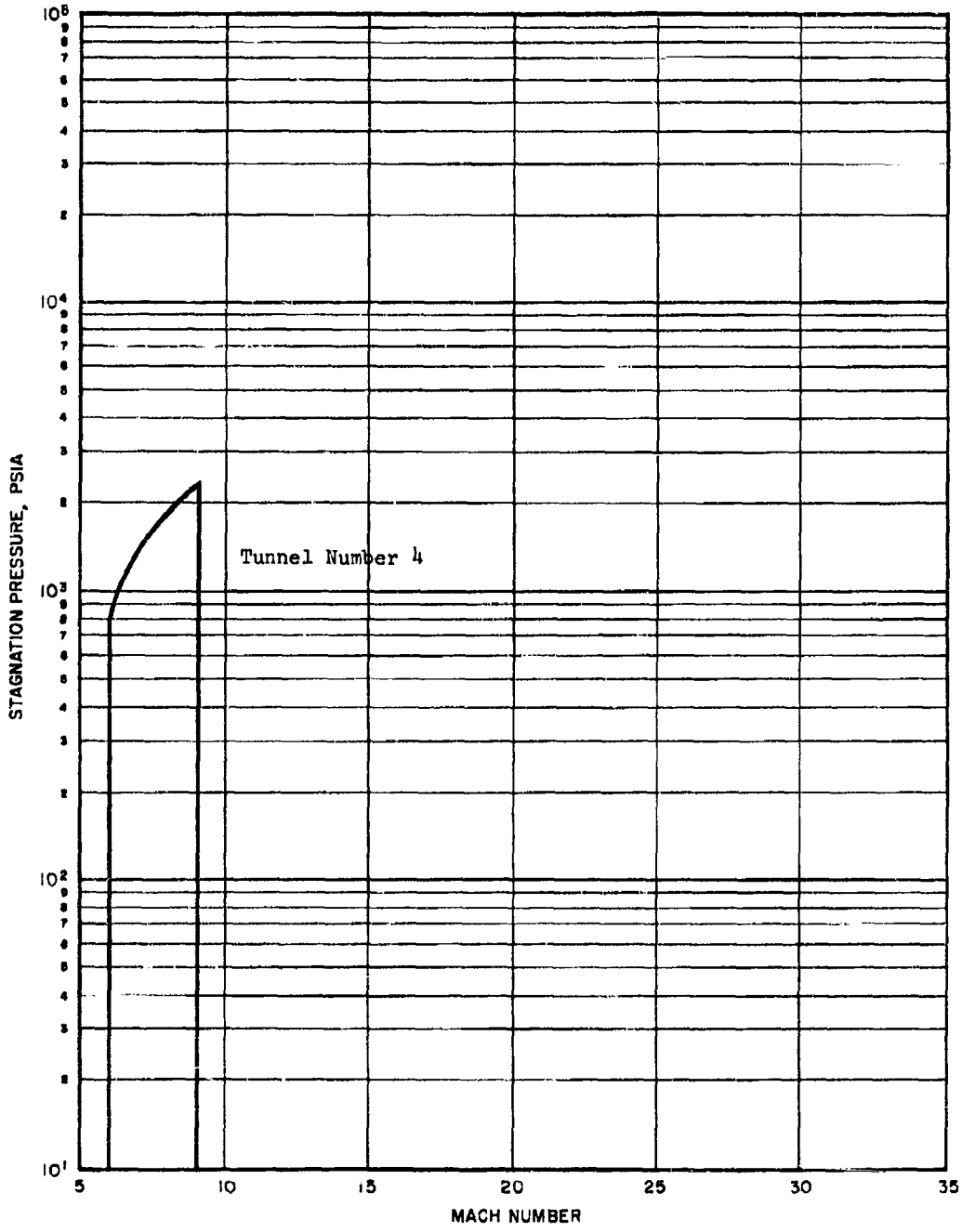
6. "Hypersonic Wind Tunnel Design, Equipment and Estimated Plant Performance," BRL TN-1221, dated October 1958.

7. Letter, C. H. Murphy to N. S. Foy, dated 26 December 1962, with enclosures.

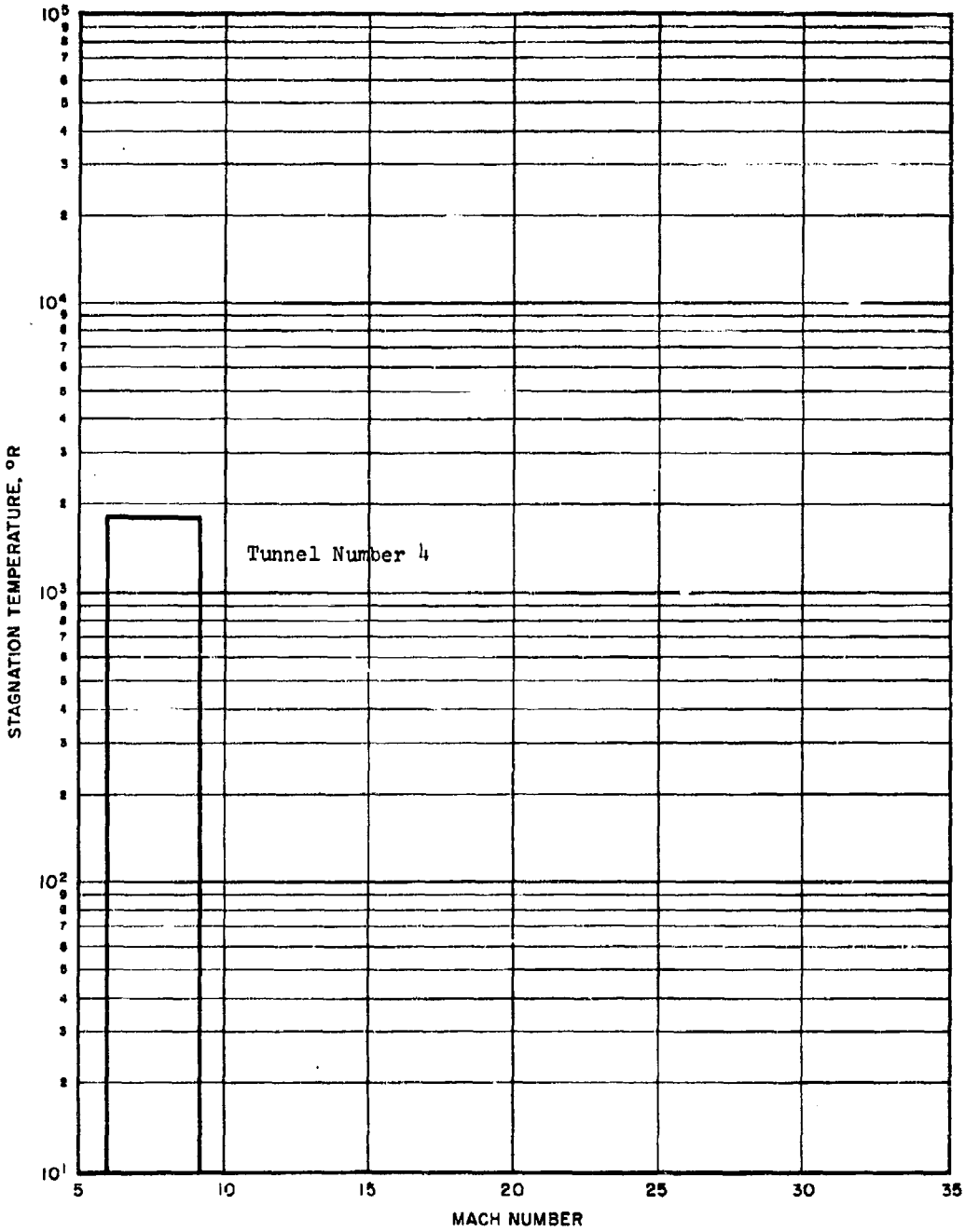
BALLISTIC RESEARCH LABORATORY
Aberdeen Proving Grounds



BALLISTIC RESEARCH LABORATORY
Aberdeen Proving Grounds



BALLISTIC RESEARCH LABORATORY
Aberdeen Proving Grounds



Name of Facility

The Boeing Company
Aero-Space Division
P. O. Box 3707
Seattle 24, Washington

Person Responsible

Mr. J. H. Russell
Chief Wind Tunnel Engineer

Type

There are three facilities in operation at Boeing. These are:

A) The 44 Inch Hotshot Wind Tunnel, which has a capacitance electrical energy storage system (7×10^6 joules, 6,000 volts and .39 farads capacitance) as a power supply.

B) The 8 Inch Hotshot Wind Tunnel.

C) The 12 Inch Hypersonic Wind Tunnel, which is of the intermittent type.

Nozzle and Test Section

A) The 44 Inch Hotshot Wind Tunnel uses a simple 10° conical nozzle, and has a 44 inch diameter test section. Models should have projected frontal area no more than 4% of test section for bodies of revolution, 3.5% for winged models. However, the tunnel can accommodate larger models at low Mach numbers.

B) The 8 Inch Hotshot Wind Tunnel uses a truncated right cone nozzle, 10° total angle, with replaceable throat sections to change Mach number. It has a cylindrical 8 inch diameter test section, and can accommodate a model with 75 square inches of frontal area at higher Mach numbers.

C) The 12 Inch Hypersonic Wind Tunnel utilizes axisymmetric contoured nozzles with 10° (included) source flow angle and parabolic contour with no transition between. The nozzle exit diameter is nominally 12 inches and exhausts as an open jet approximately 14 inches long. Delta-wing models have been tested up to angles which produce frontal area projections 7% of physical nozzle exit area. Hemispheres with frontal area projections 10% of physical nozzle exit area have also been run.

Instrumentation and Test Capabilities

All three facilities have been used to measure pressure, temperature and force. Data reduction is by computer.

Running Times

A) 44 Inch Hotshot Wind Tunnel - 60 to 300 milliscconds.

B) 8 Inch Hotshot Wind Tunnel - 30 to 40 milliseconds.

C) 12 Inch Hypersonic Wind Tunnel - 20 to 100 seconds.

Remarks

The test gas used in the 44 inch facility is air. The particle contamination due to the erosion of the electrodes in on the order of 1% or less of the air density in the test section.

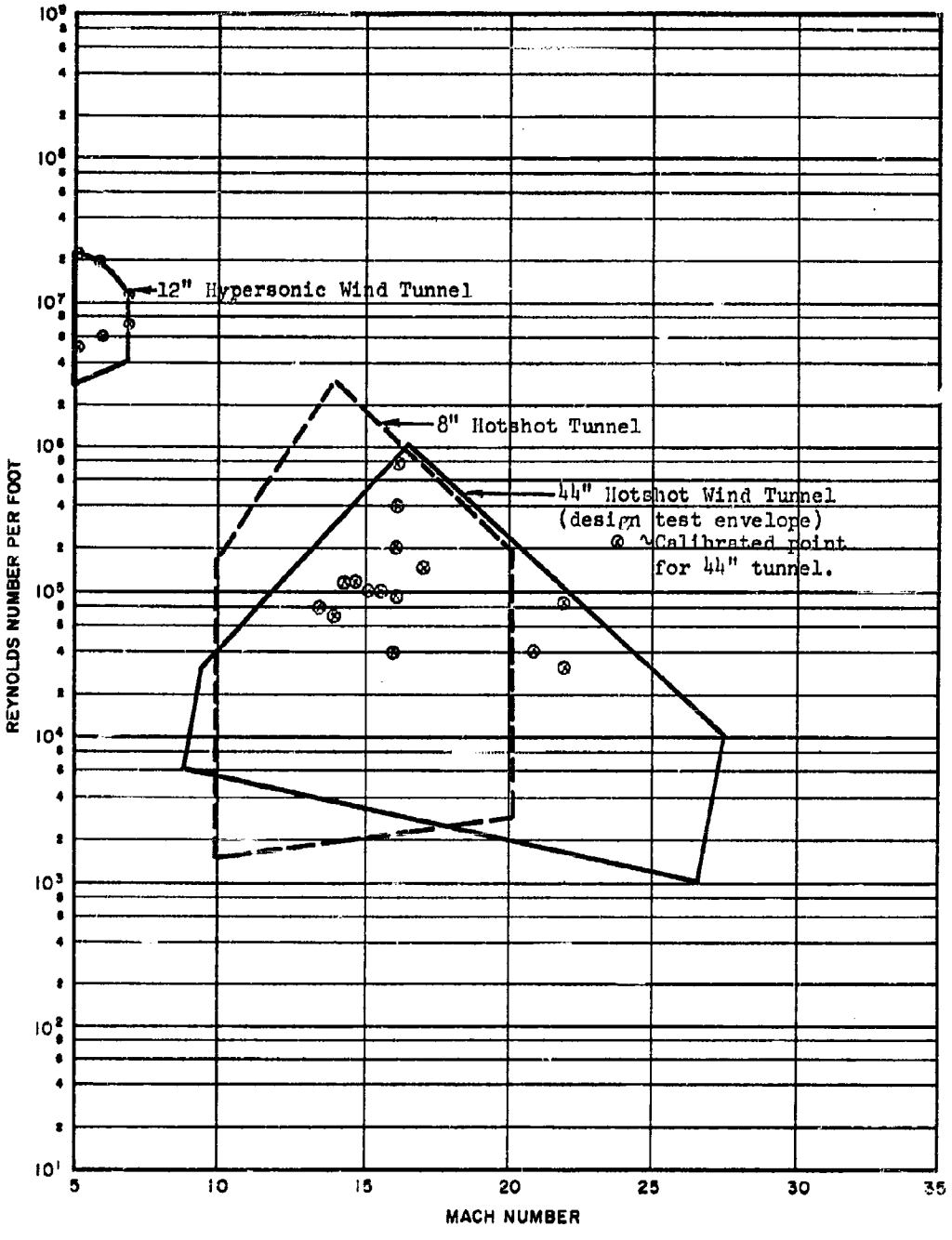
References

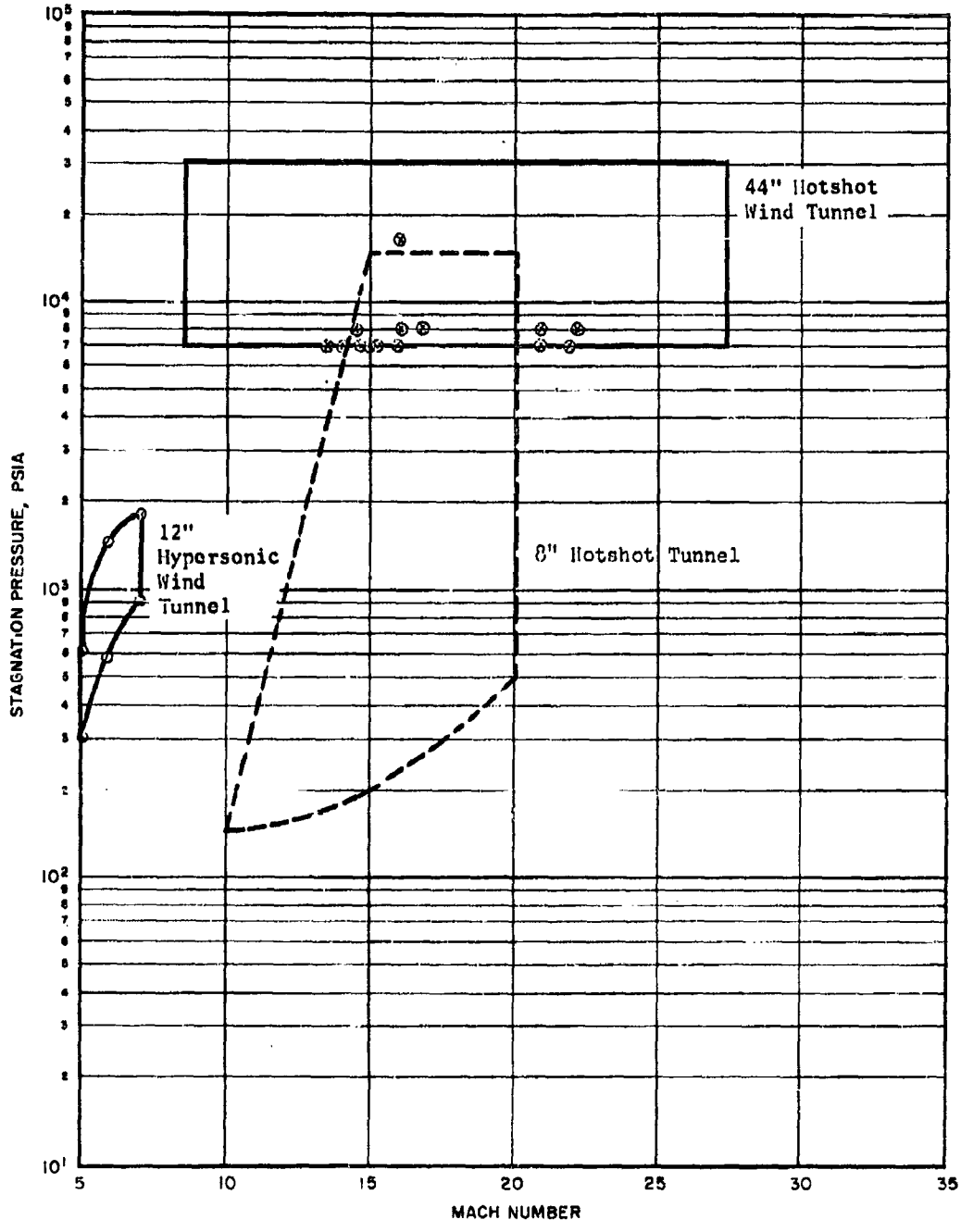
1. "The Boeing 44 Inch Hotshot Wind Tunnel", by W. G. Harris and R. M. Miller (for the Joint Bumblebee Panel Meeting, November 1961).

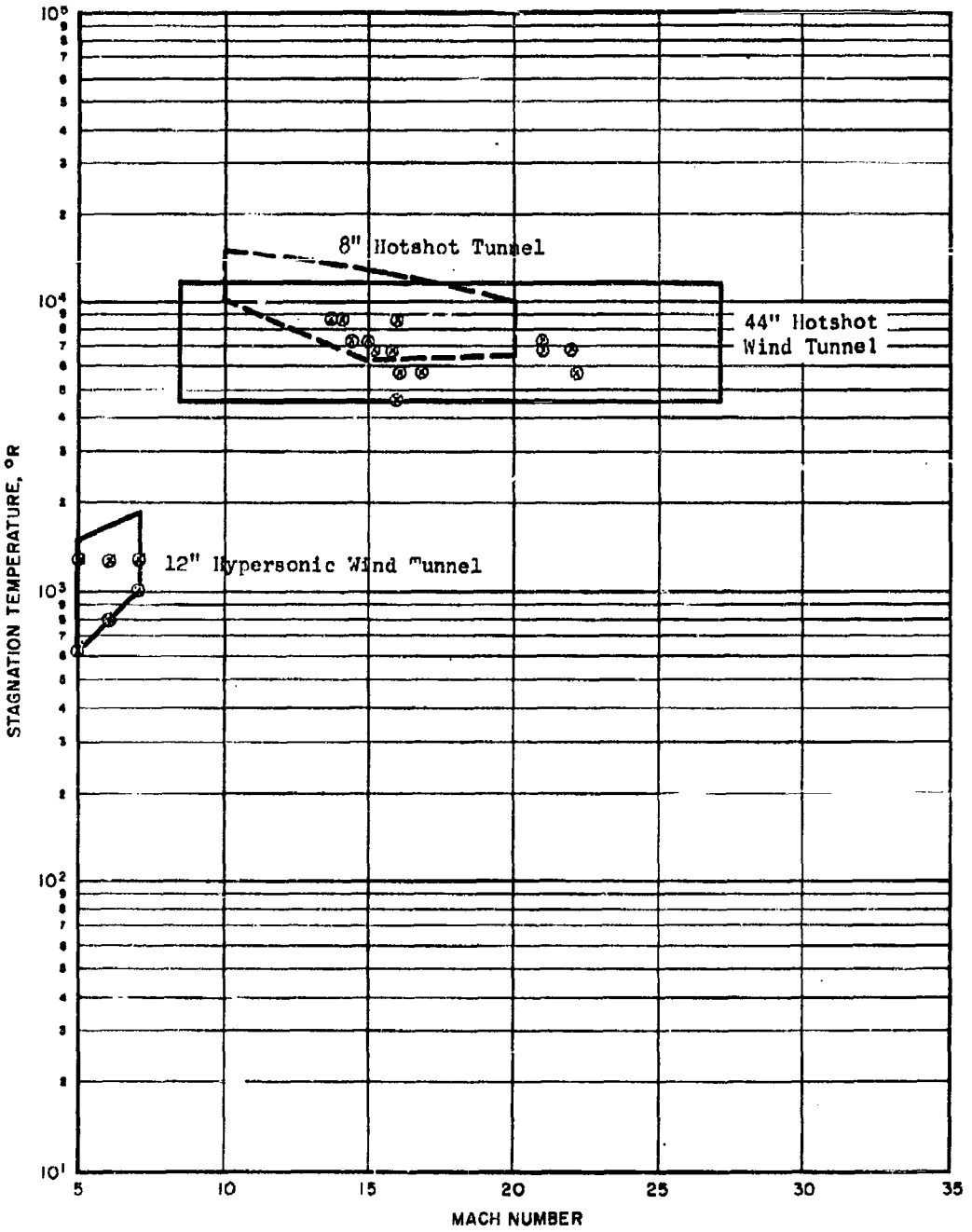
2. Letter, J. H. Russell to F. A. Vicente, undated, number 2-5752-5.

3. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, dated April 1960.

4. Letter, J. H. Russell to N. S. Foy, dated 26 December 1962, number 2-5751-00-90, with enclosures.


12" Hypersonic Wind Tunnel
8" Hotshot Tunnel
44" Hotshot Wind Tunnel
(design test envelope)
⊗ Calibrated point
for 44" tunnel.
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


44" Hotshot
Wind Tunnel
12"
Hypersonic
Wind
Tunnel
8" Hotshot Tunnel
STAGNATION PRESSURE, PSIA
MACH NUMBER
10⁵
10⁴
10³
10²
10¹
5
10
15
20
25
30
35


8" Hotshot Tunnel
44" Hotshot
Wind Tunnel
12" Hypersonic Wind Tunnel
STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

Hypervelocity Wind Tunnel
Chance-Vought Corporation
P. O. Box 5907
Dallas 22, Texas

Person Responsible

Mr. R. C. McWherter, Chief, Wind Tunnel Laboratories
Mr. C. J. Stalmach, Jr., Supervisor, Hypervelocity Wind Tunnel

Type

The 13 inch Hypervelocity Tunnel is of the arc driven hotshot type, utilizing a capacitor bank for power storage.

Nozzle and Test Section

This facility uses a 7.5° total angle conical nozzle expanding to a 13 inch diameter test section. The useable test core size is 5 inches in diameter at M = 17.

Instrumentation and Test Capabilities

Force, pressure, heat transfer and dynamic damping tests may be run in this facility. Special tests have also been made, such as rocket exhaust effects on vehicle stability and transpiration cooling experiments.

Running Time

Running times in this facility vary from 40 to 80 milliseconds depending on test conditions.

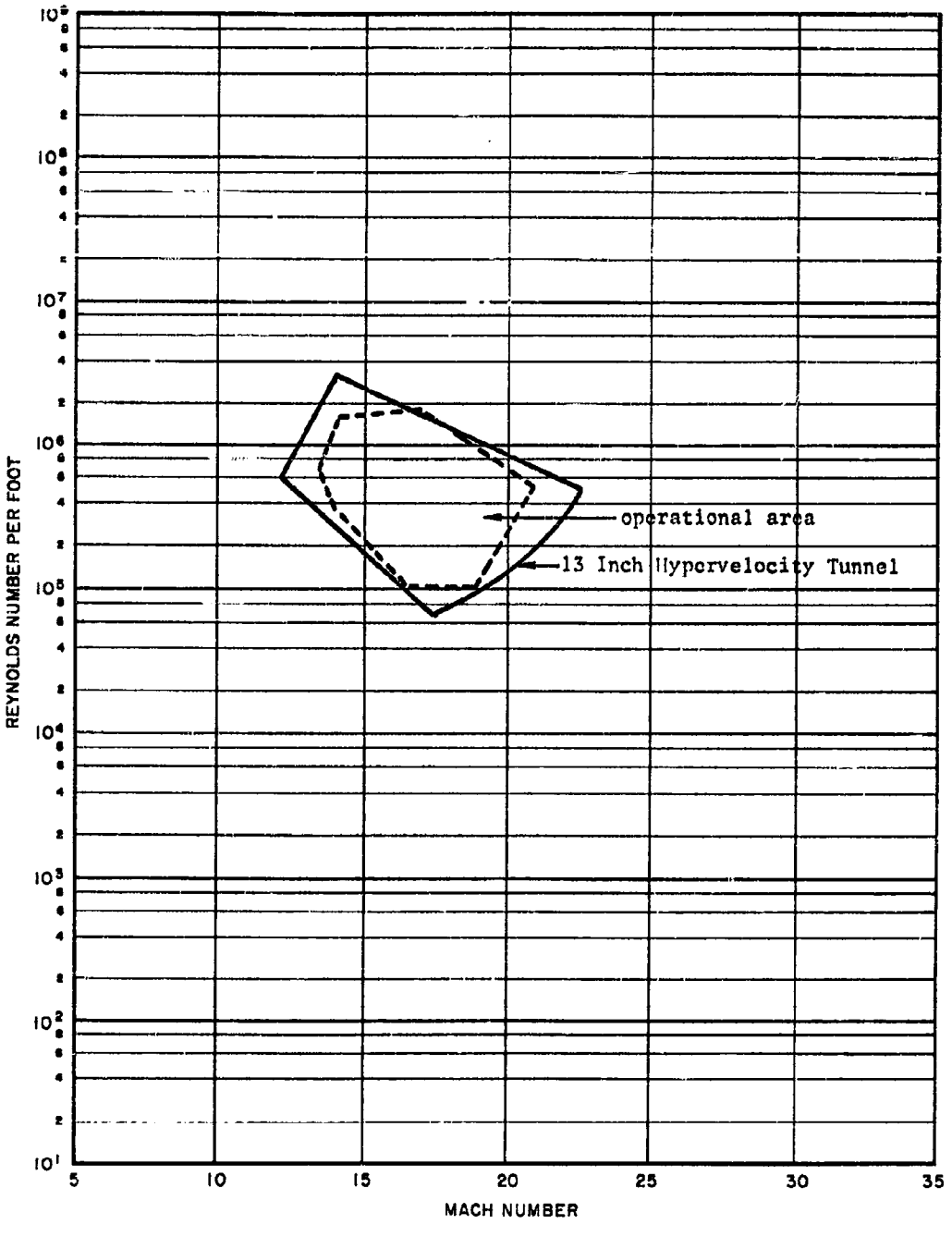
Remarks

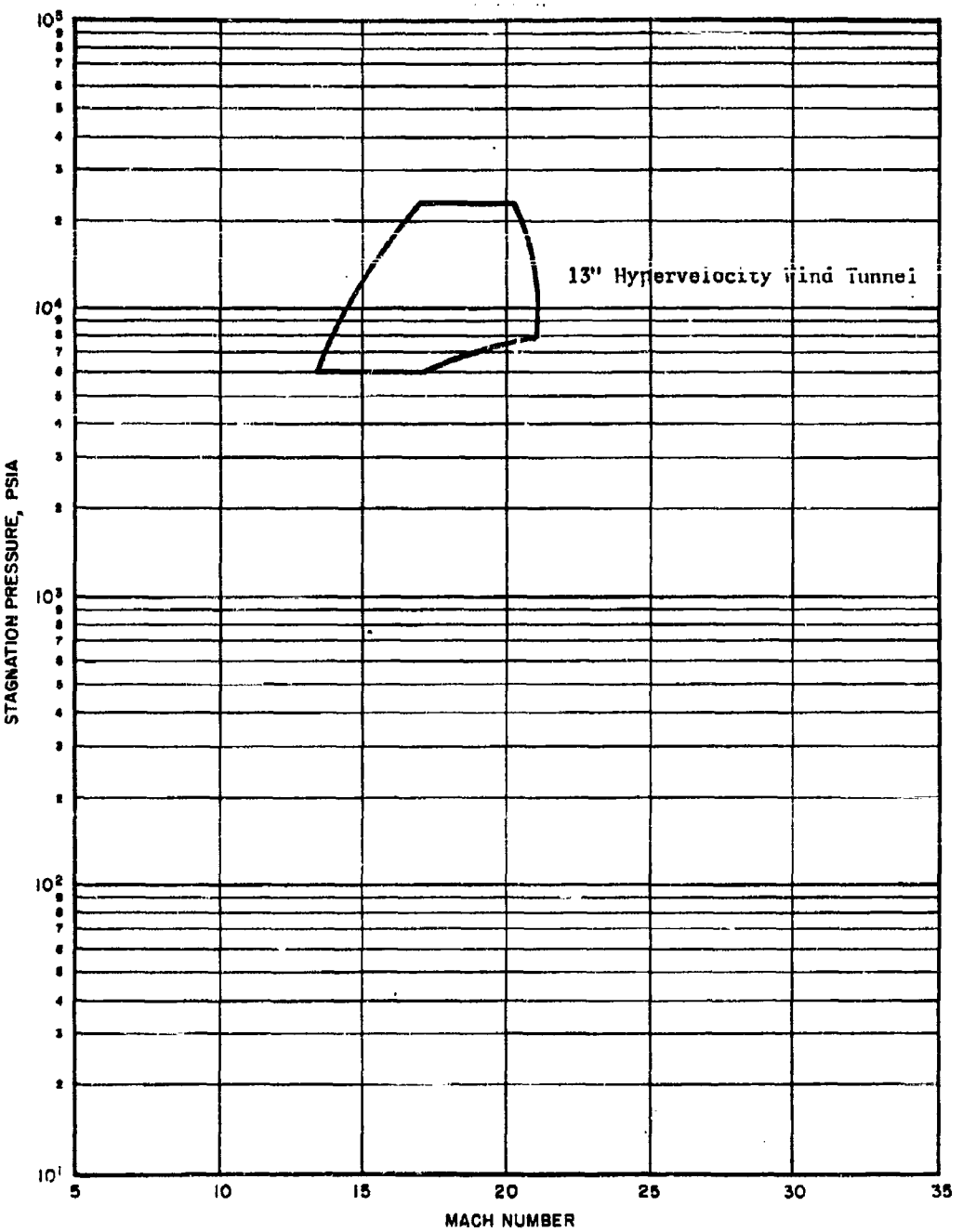
The test gas used is nitrogen, although air has been used. Contamination of flow for this facility is extremely low.

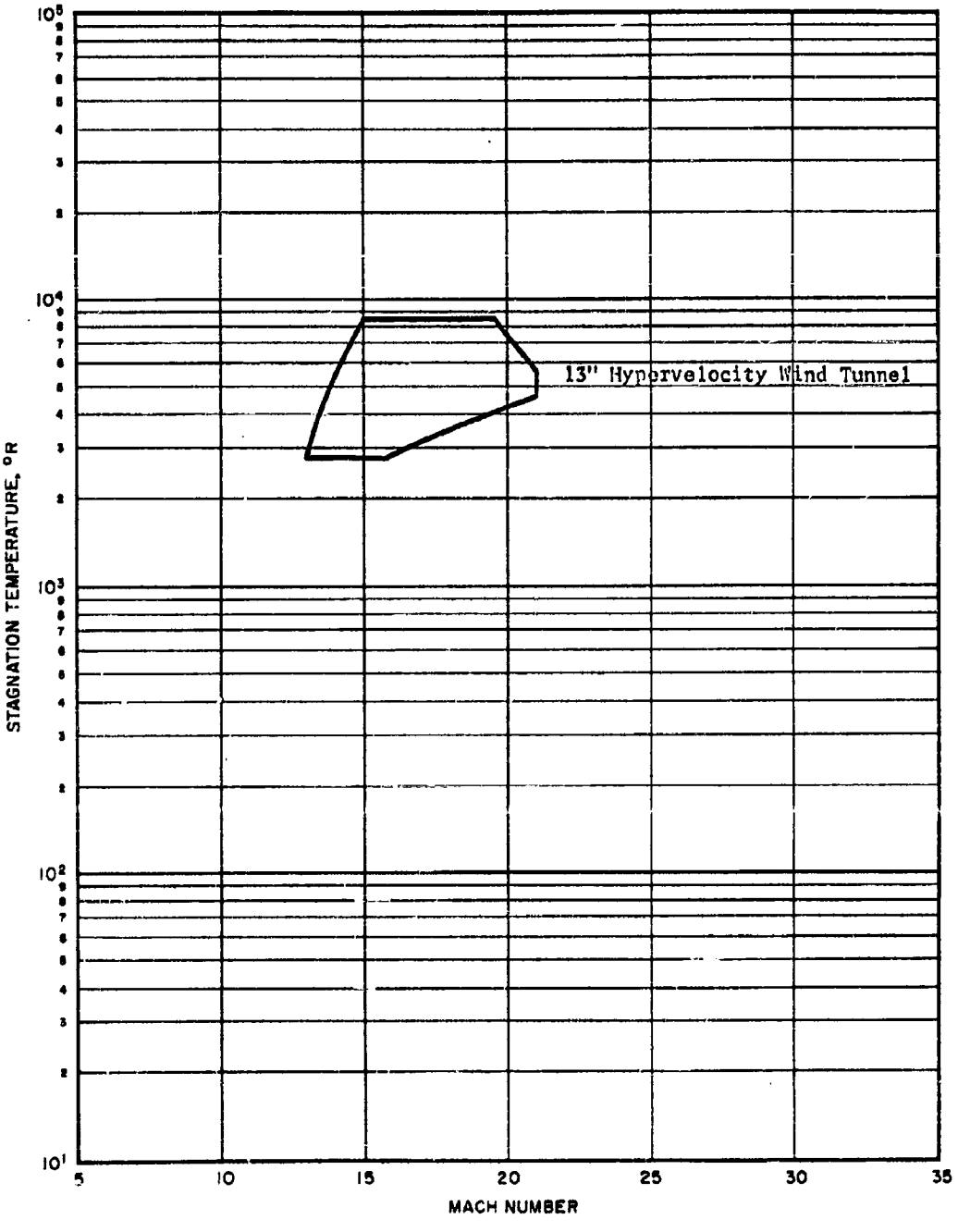
References

1. "Present Performance Envelope of the Hypervelocity Wind Tunnel," by C. J. Stalmach, dated December 1961.

2. Letter, R. C. McWherter to N. S. Foy, LTV No. AER-WTL-474, dated 26 December 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
operational area
13 Inch Hypervelocity Tunnel


13" Hypervelocity Wind Tunnel
STAGNATION PRESSURE, PSIA
MACH NUMBER
5
10
15
20
25
30
35


13" Hypervelocity Wind Tunnel
STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

Cornell Aeronautical Laboratory, Inc.
4455 Genessee Street
Buffalo 21, New York

Person Responsible

Mr. K. D. Bird - Shock Tunnel Facilities
Mr. John P. Andes - Wave Superheater Hypersonic Tunnel

Type

The following facilities are available at Cornell:

A) 48 Inch Hypersonic Shock Tunnel

B) High-Energy Shock Tunnel

C) Wave Superheater Hypersonic Tunnel, which is a long duration high temperature hypersonic tunnel.

Nozzle and Test Section

A) Conical nozzles are used for most of the Mach number range in the 48 inch Tunnel. Contoured M = 8 and M = 16 nozzles are also used with the 48 inch Tunnel.

B) The same nozzles, along with a conical nozzle 8 feet in diameter will be used with the High-Energy Shock Tunnel.

C) The Wave Superheater utilizes a conical nozzle expanded to a Mach 6 test section with nozzle exit of 8 inches and a conical nozzle expanded to Mach 15 test section with nozzle exit of 9.5 feet. Intermediate test sections are possible with some modifications, and details are presently being studied.

Instrumentation and Test Capabilities

A) and B) Force, pressure and heat transfer tests may be performed in these facilities.

C) Force, pressure and heat transfer tests may be performed in the Wave Superheater, as well as Ablation and Materials Studies and Structural tests. Due to large test section, full scale or near full scale model testing is possible.

Running Times

A) 48 Inch Hypersonic Shock Tunnel - 4 to 12 milliseconds.

B) High-Energy Shock Tunnel - 4 to 12 milliseconds.

C) Wave Superheater Hypersonic Tunnel - Running time can be varied from 1 second to 15 seconds.

Remarks

A) The 48 Inch Tunnel is fully operational and calibrated.

B) The High-Energy Tunnel is in the construction phase. It is expected to be operational late in 1963.

C) Contracted tests have been conducted on ablation experiments in the Mach 6 test section of the Wave Superheater. The Mach 15 test section is presently being calibrated. Full capability of the Wave Superheater has not yet been attained. Maximum output thus far has been 6500°R and 100 atms.

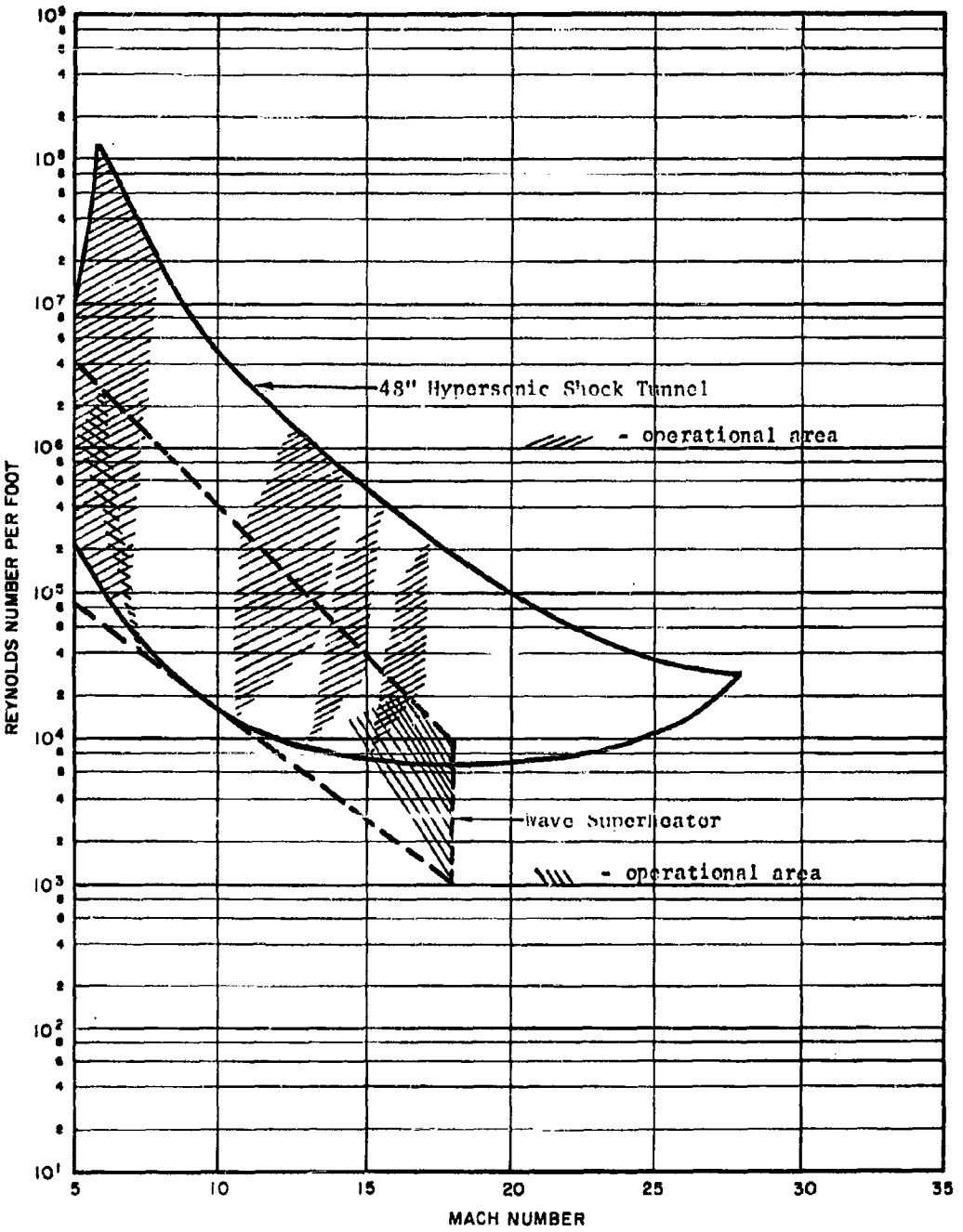
References

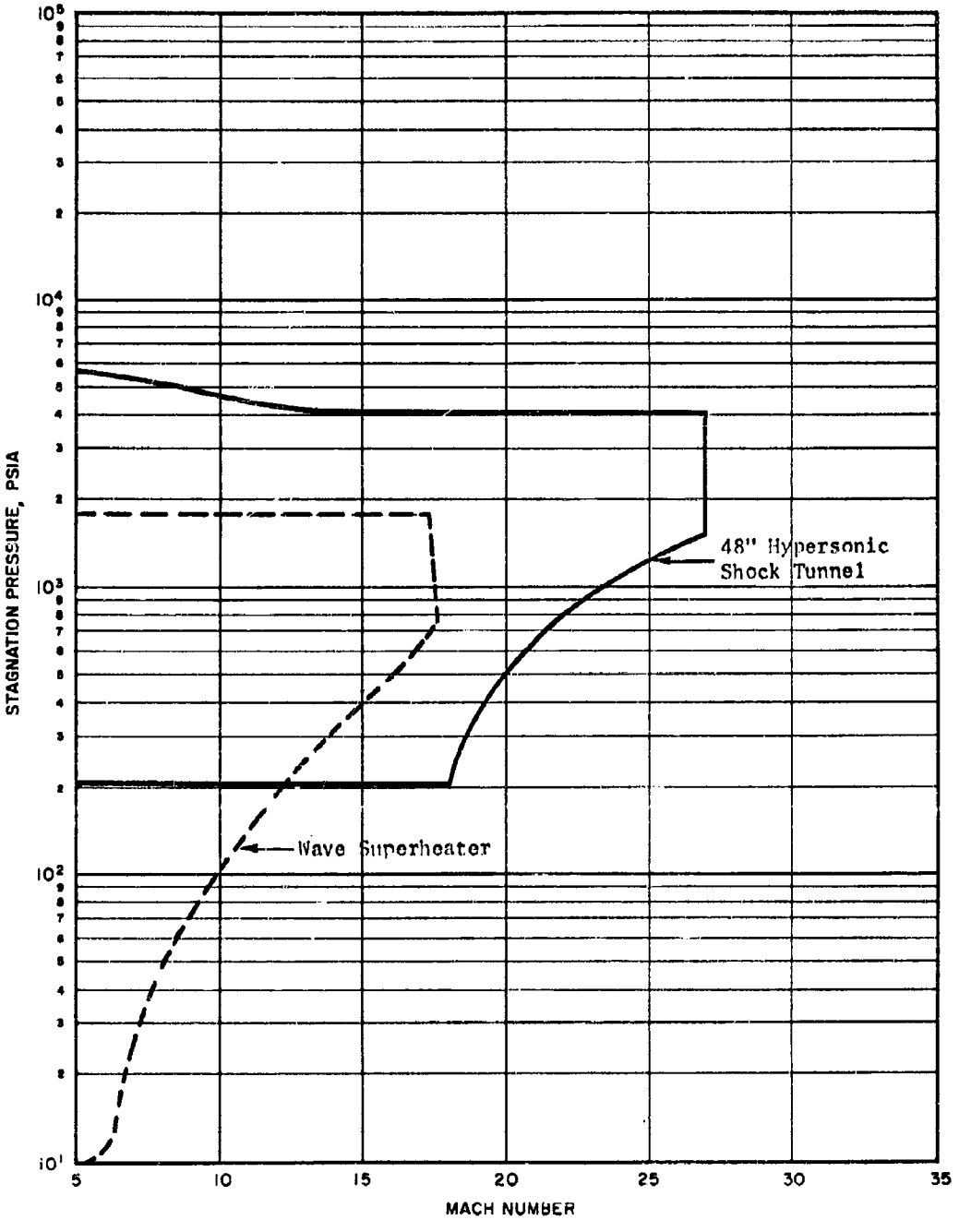
1. "Cornell Aeronautical Laboratory 48 Inch Hypersonic Shock Tunnel, Description and Capabilities," revised December 1962.

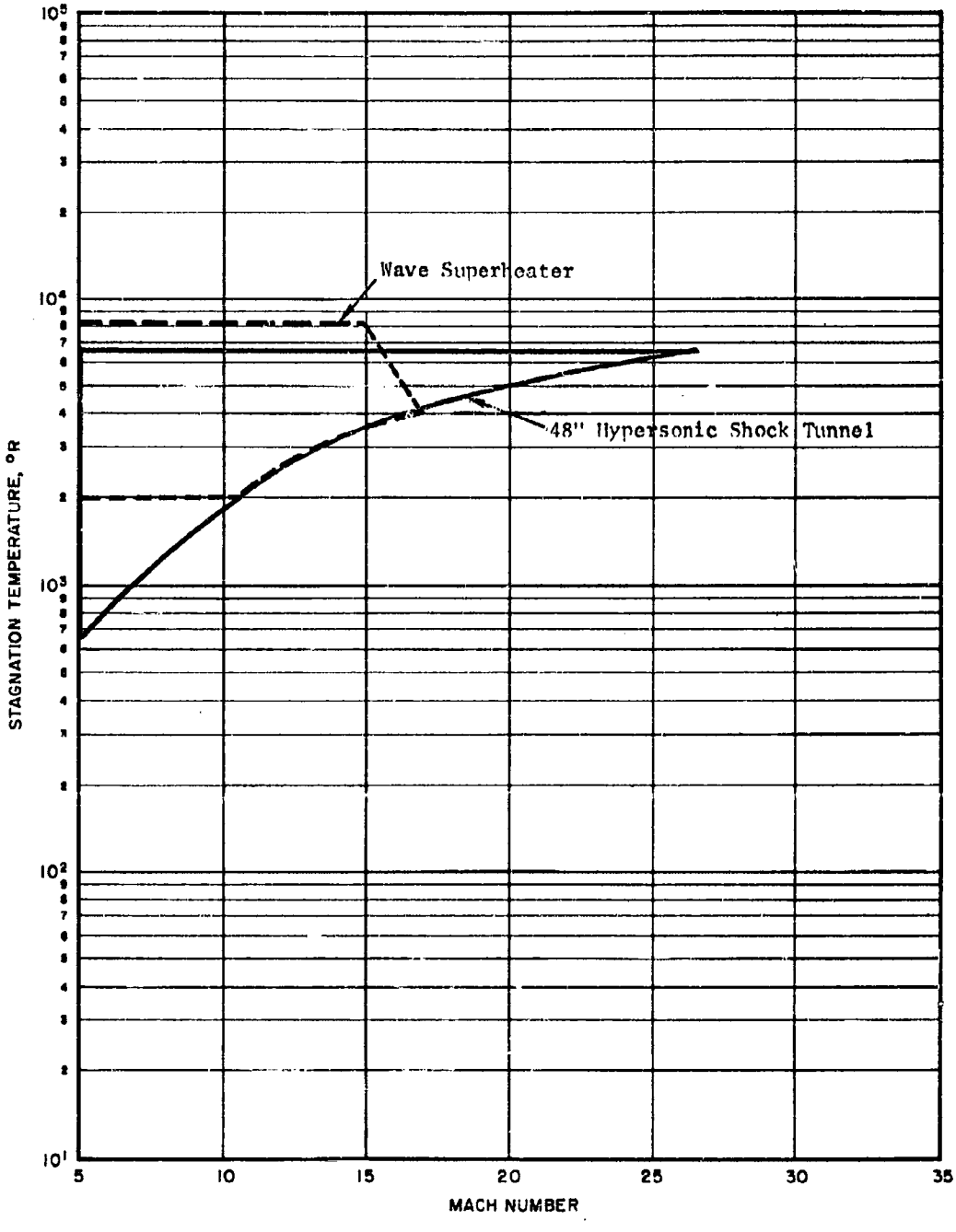
2. "Cornell Aeronautical Laboratory Wave Superheater Hypersonic Tunnel, Description and Capabilities," October 1962.

3. Letter, K. D. Bird to N. S. Foy, dated 9 January 1963, with enclosures.

4. Letter, John P. Andes to N. S. Foy, dated 17 January 1963, with enclosures.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
48" Hypersonic Shock Tunnel
- operational area
Wave Superheator
- operational area


STAGNATION PRESSURE, PSIA
MACH NUMBER
48" Hypersonic
Shock Tunnel
Wave Superheater


Wave Superheater
48" Hypersonic Shock Tunnel
STAGNATION TEMPERATURE, °R
MACH NUMBER
10⁵
10⁴
10³
10²
10¹
5
10
15
20
25
30
35

Name of Facility

Aerophysics Laboratory
Douglas Aircraft Company
Missile and Space Systems Division
Santa Monica, California

Person Responsible

Dr. J. Murphy

Type

Two types of tunnels are operational or in the calibration stage at present. These are:

A) The Hypersonic Two-Foot Tunnel, of the blowdown type, which utilizes a pebble-bed heater.

B) The Hypervelocity Impulse Tunnel, which is a combustion driven shock tunnel.

Nozzle and Test Section

A) The Two-Foot Tunnel utilizes contoured nozzles which yield a test core of roughly 22 inches diameter for M = 6, 8 and 10.

B) The shock tunnel utilizes a conical nozzle with a 30 inch exit diameter and interchangeable throats to produce Mach numbers between 9.5 and 28, depending on geometric area ratio and reservoir pressure and enthalpy level.

Instrumentation and Test Capabilities

Heat transfer, force and pressure measurements may be made in this facility.

Running Times

A) Two-Foot Tunnel - 40 seconds.

B) Shock tunnel - will have running times of about 10 milliseconds.

Remarks

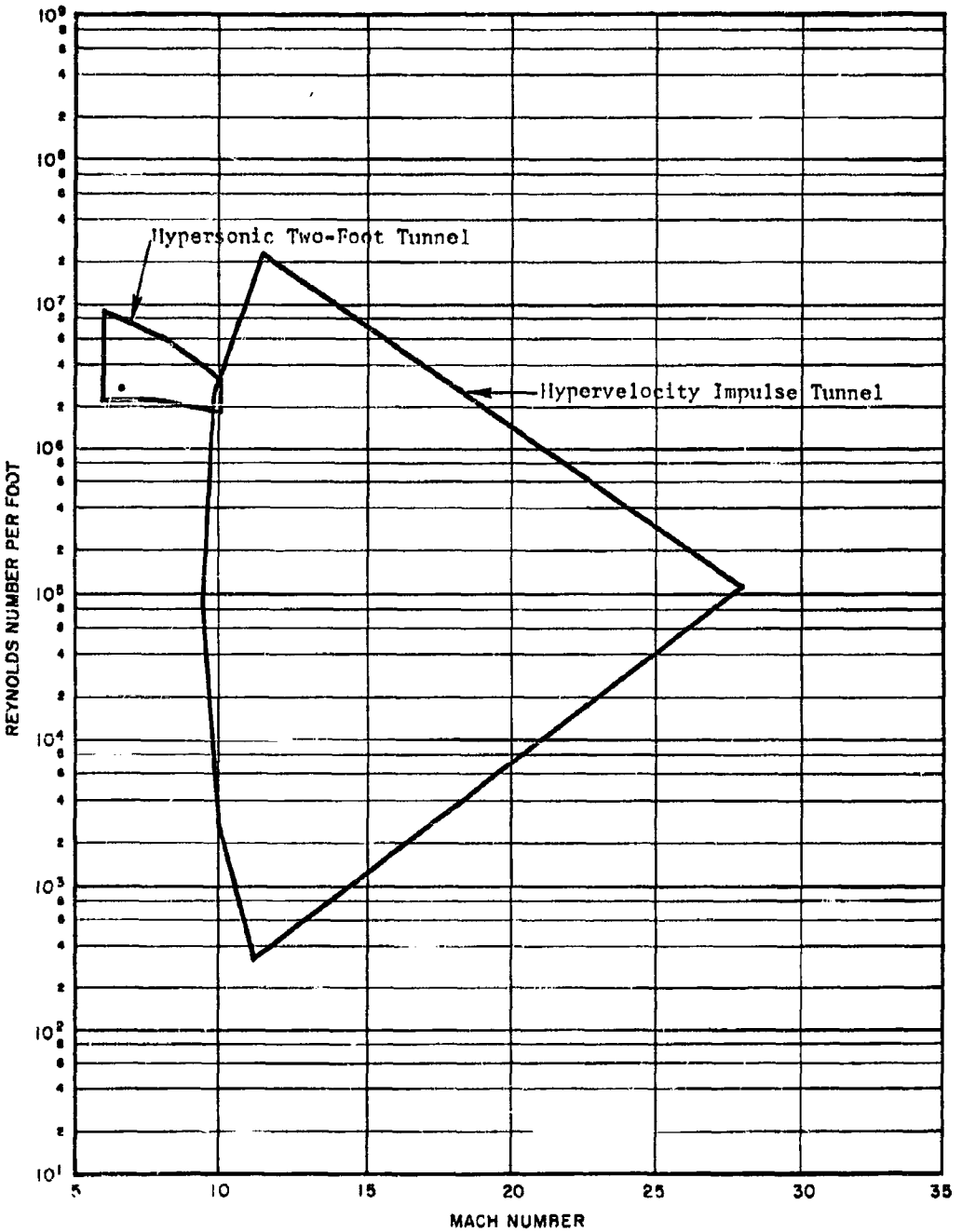
The Two-Foot Tunnel has just recently become operational, while the shock tunnel is being calibrated.

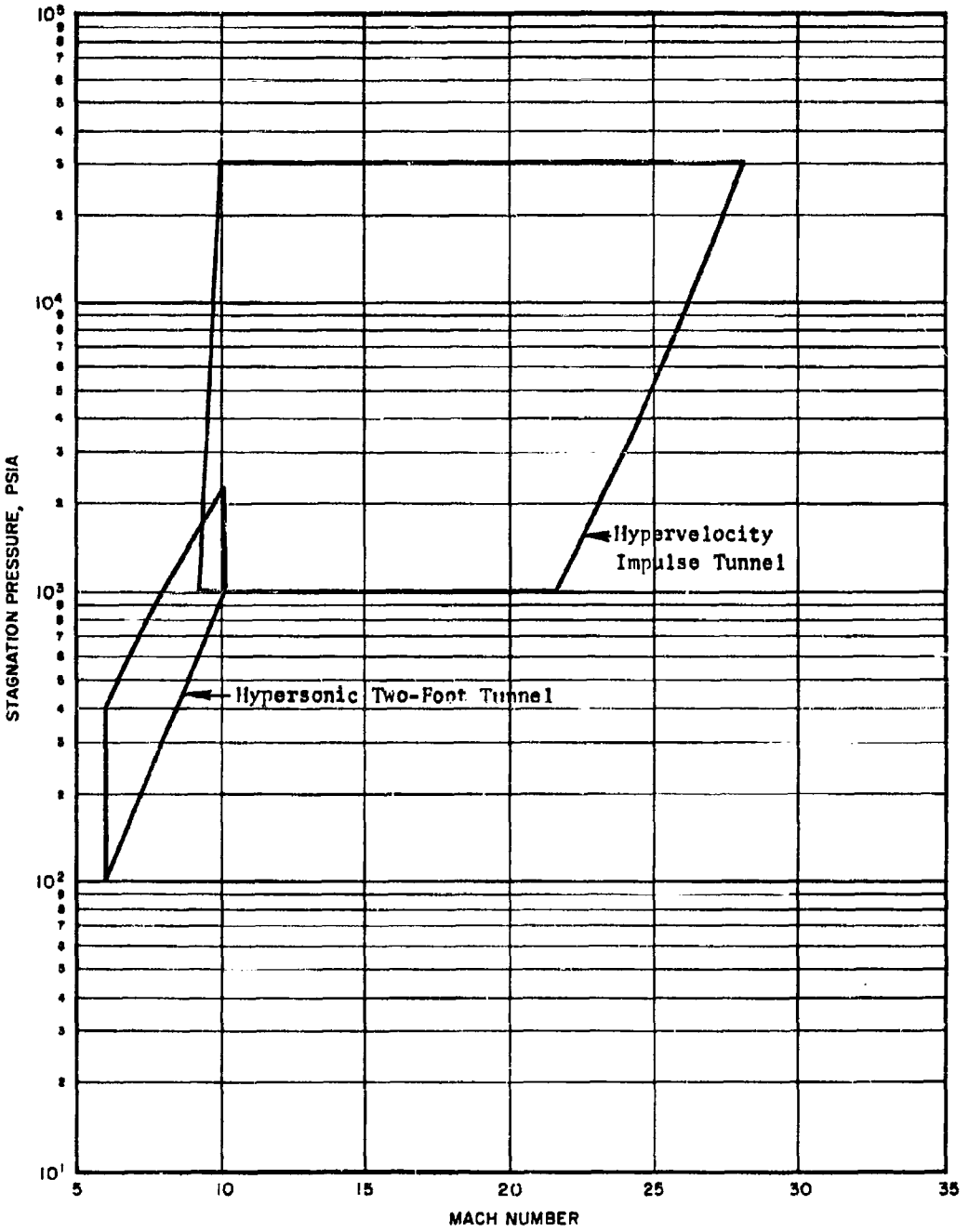
References

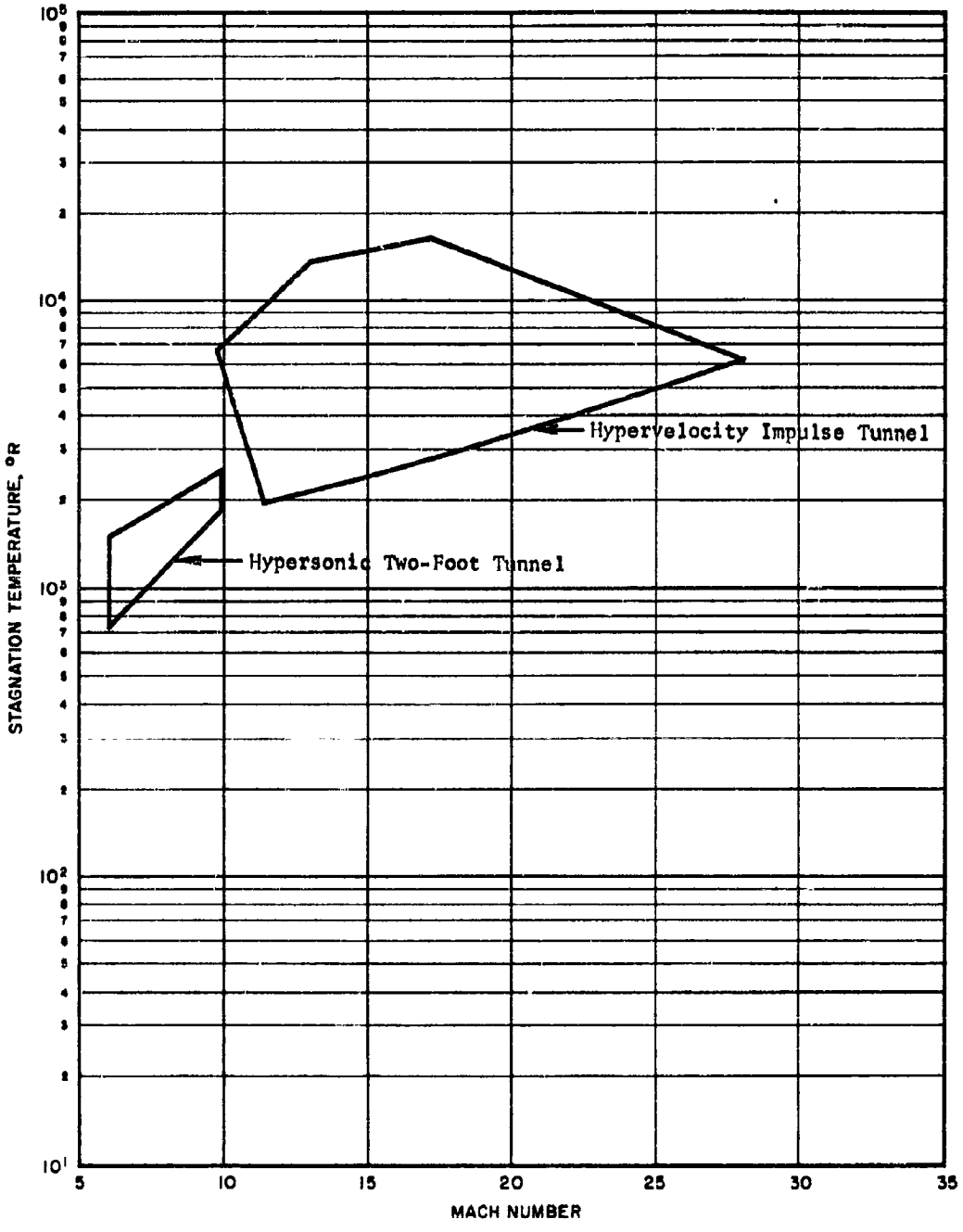
1. Brochure, Aerophysics Laboratory, Douglas Aircraft Company, Inc.

2. Personal communication, J. Murphy and F. A. Vicente.

3. Letter, W. H. P. Drummond to N. S. Foy, Number A200-R/A-L376, dated 14 December 1962.


Hypersonic Two-Foot Tunnel
Hypervelocity Impulse Tunnel
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
Hypervelocity
Impulse Tunnel
Hypersonic Two-Foot Tunnel


STAGNATION TEMPERATURE, °R
MACH NUMBER
Hypervelocity Impulse Tunnel
Hypersonic Two-Foot Tunnel
5
10
15
20
25
30
35

Name of Facility

FluiDyne 20 Inch Hypersonic Tunnel
FluiDyne Engineering Corporation
5900 Olson Memorial Highway
Minneapolis 22, Minnesota

Person Responsible

Dr. James S. Holdhusen, Vice President

Type

This facility is of the blowdown hypersonic wind tunnel type, utilizing a gas-fired zirconia pebble-bed storage heater.

Nozzle and Test Section

Fully contoured nozzles are used to develop uniform hypersonic flow fields in a free-jet test section. Models are inserted into the test stream after the flow has been stabilized. The model support mechanism can cover 90° of pitch range during a run at pitch rates from 1 to 20 degrees per second. The test cabin has dimensions of 64 x 60 x 40 inches. Usable test core dimensions range from 6.5 at M = 7 to 9.0 at M = 14.

Instrumentation and Test Capabilities

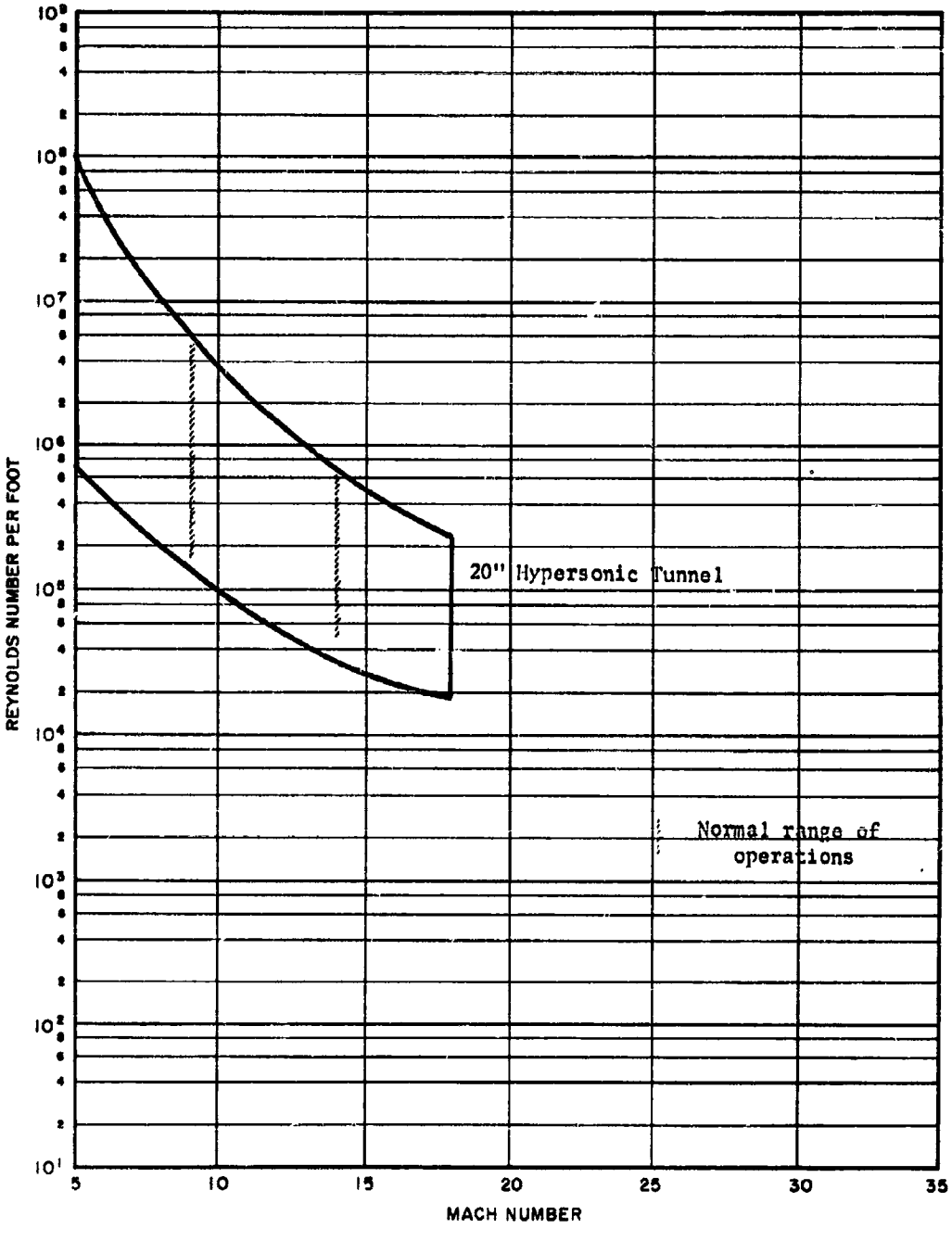
Force, pressure, heat transfer, flow field surveys and dynamic stability tests have been run in the facility. Tests may be conducted with models initially subcooled to -320°F or heated to elevated temperatures to investigate the effect of wall-to-free-stream temperature ratio.

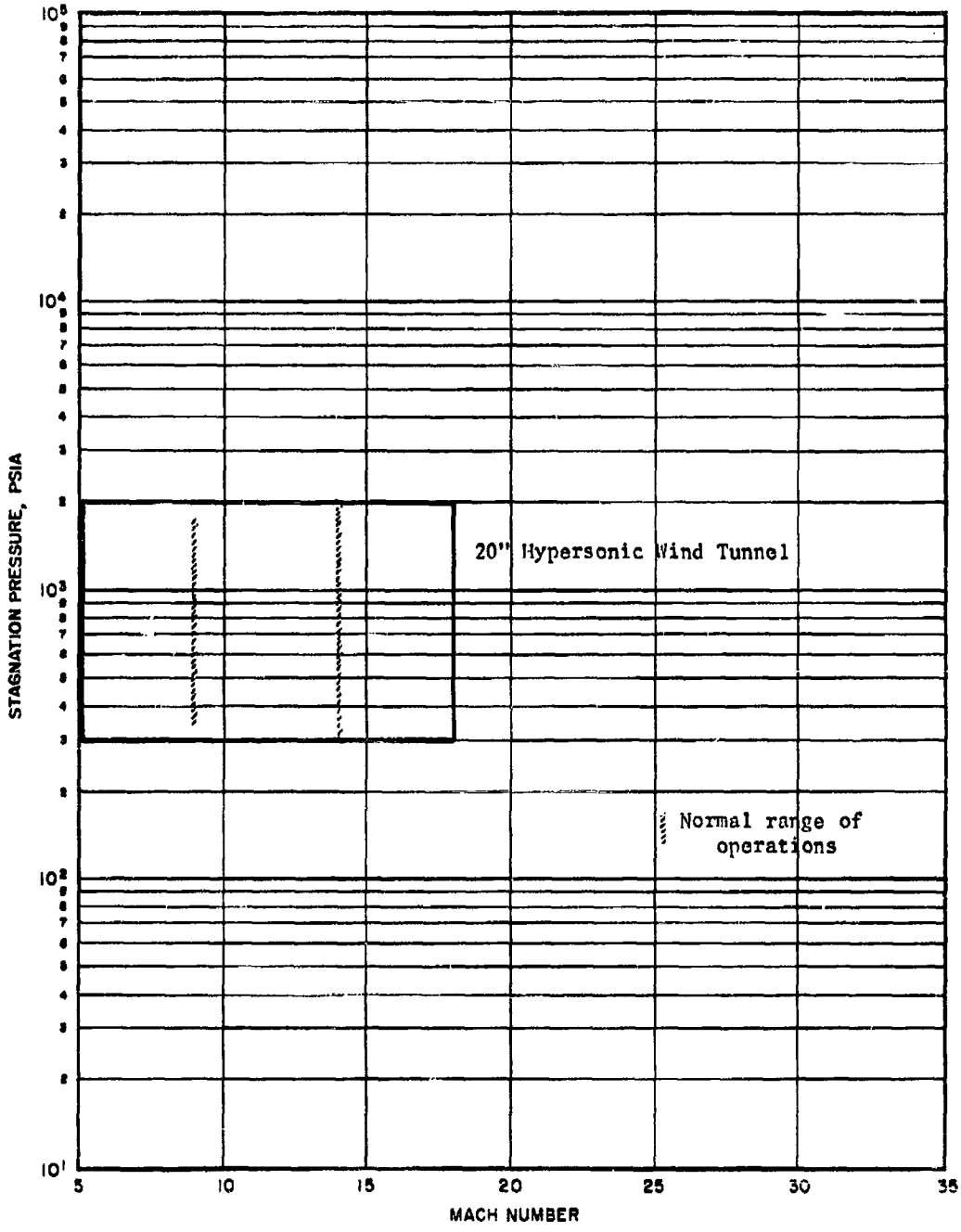
Running Time

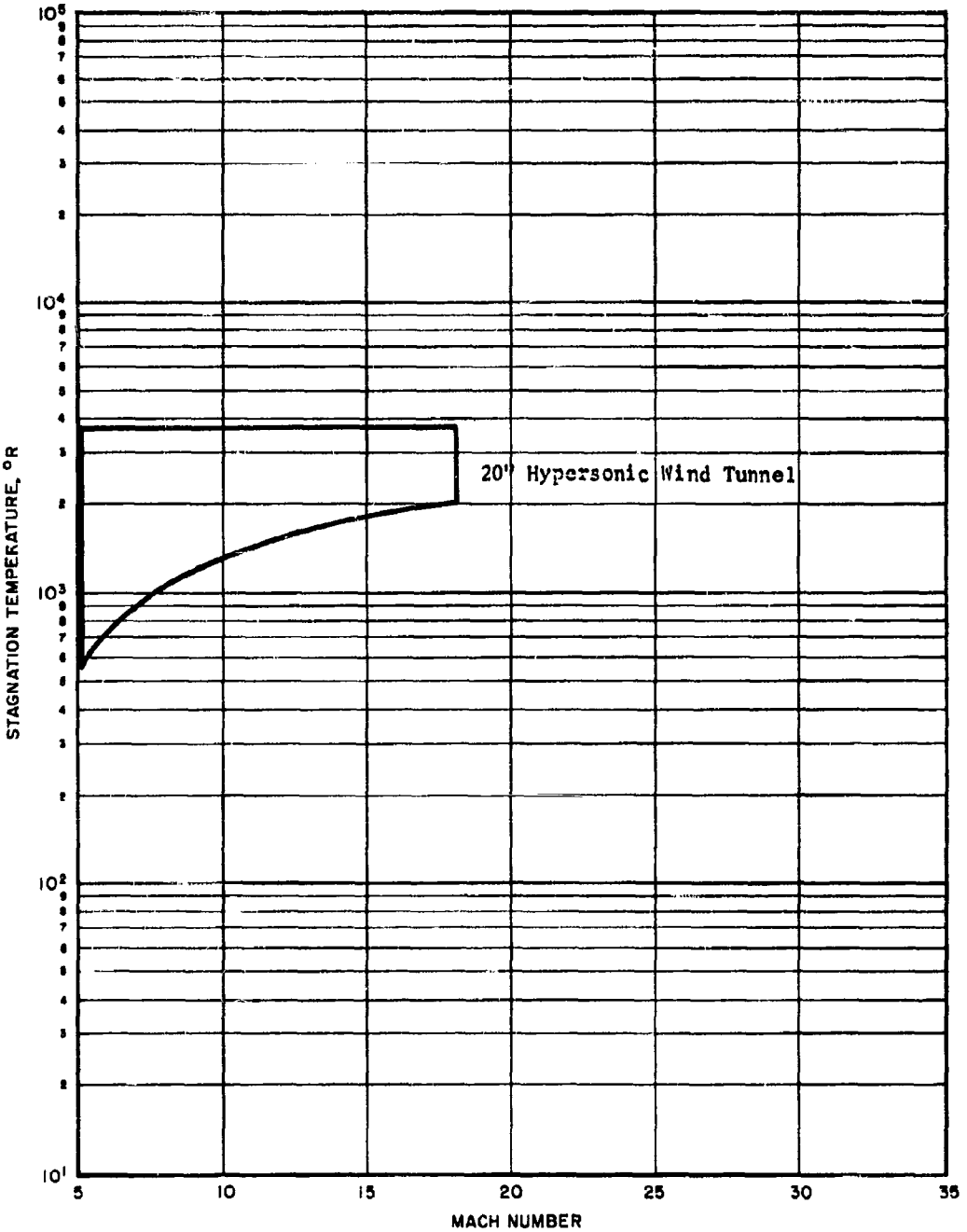
Running time varies with Mach number and temperature, but is generally about 90 seconds.

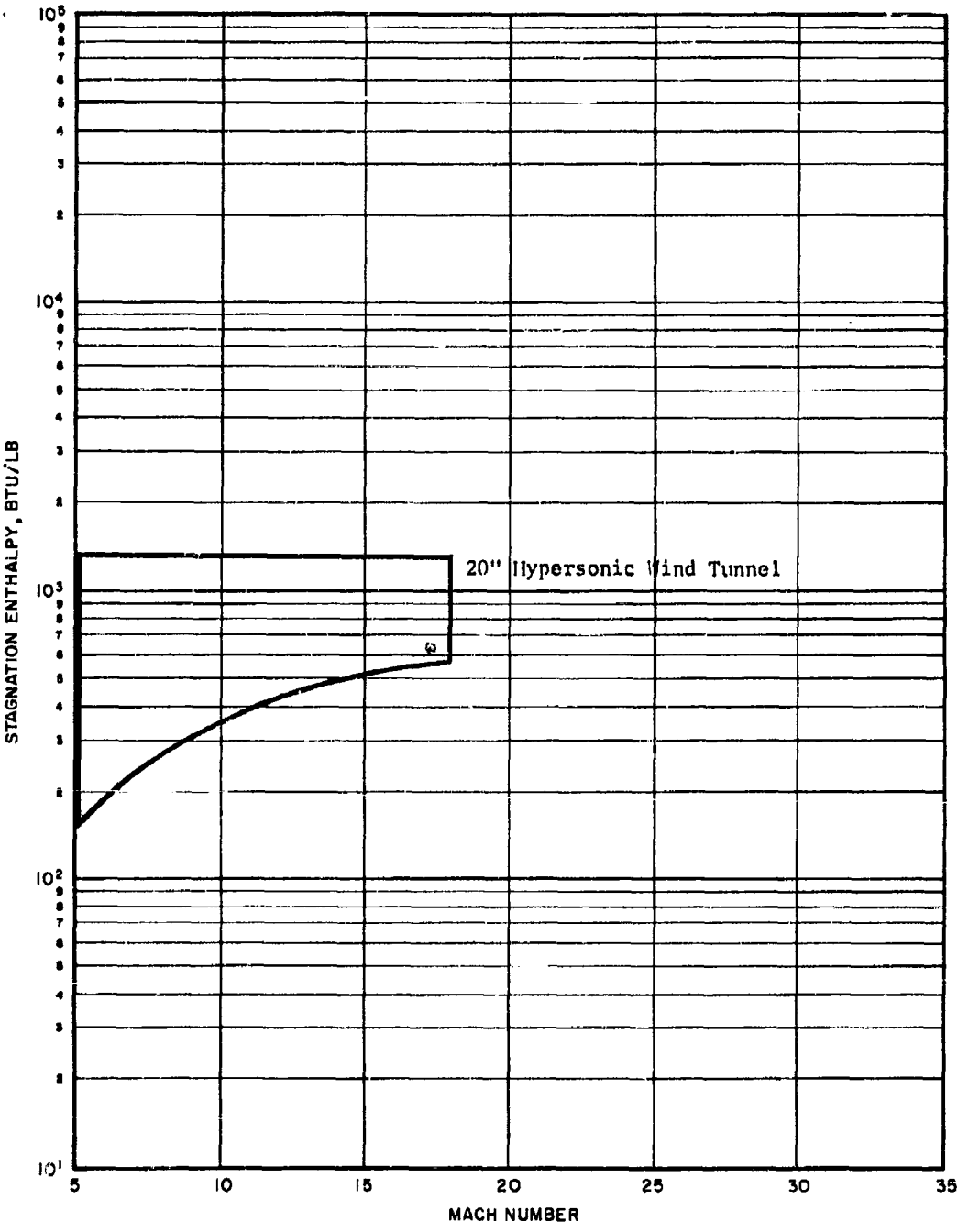
References

1. "Fluidyne Aerodynamic Laboratories," brochure.
2. Letter, J. L. Frame to F. A. Vicente, dated 21 March 1962.
3. Letter, J. S. Holdhusen to N. S. Foy, dated 27 December 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35
20" Hypersonic Tunnel
Normal range of operations


STAGNATION PRESSURE, PSIA
MACH NUMBER
20" Hypersonic Wind Tunnel
Normal range of operations
5
10
15
20
25
30
35


STAGNATION TEMPERATURE, °R
MACH NUMBER
20" Hypersonic Wind Tunnel
10⁵
10⁴
10³
10²
10¹
5
10
15
20
25
30
35


STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
20" Hypersonic Wind Tunnel
5
10
15
20
25
30
35

Name of Facility

Convair Hypersonic Shock Tunnel
General Dynamics/Convair
Post Office Box 1950
San Diego 12, California

Person Responsible

D. P. Cumming, Mail Zone 61-10

Type

The Convair facility is a combustion driven shock tunnel with a Mach number range of 5.6 to 25.

Nozzle and Test Section

The Hypersonic Shock Tunnel utilizes a conical expansion nozzle with a 13° total divergence angle and 27.6 inch exit diameter. The throat diameter may be varied from 0.05 to 0.75 inches by using interchangeable throat inserts. 4-6 inch diameter bodies may be tested in this facility.

Instrumentation and Test Capabilities

The Convair facility is used for the purpose of aerodynamic research and development. The driver for this facility is also utilized for particle projection in micrometeorite impingement studies. A program of improvement is underway in the area of aerodynamic testing, involving extension of data recording capabilities and reduction of driver contaminants in the airflow.

Running Time

Theoretical airflow duration would be from 4 to 55 milliseconds with 0.45 inch throat diameter.

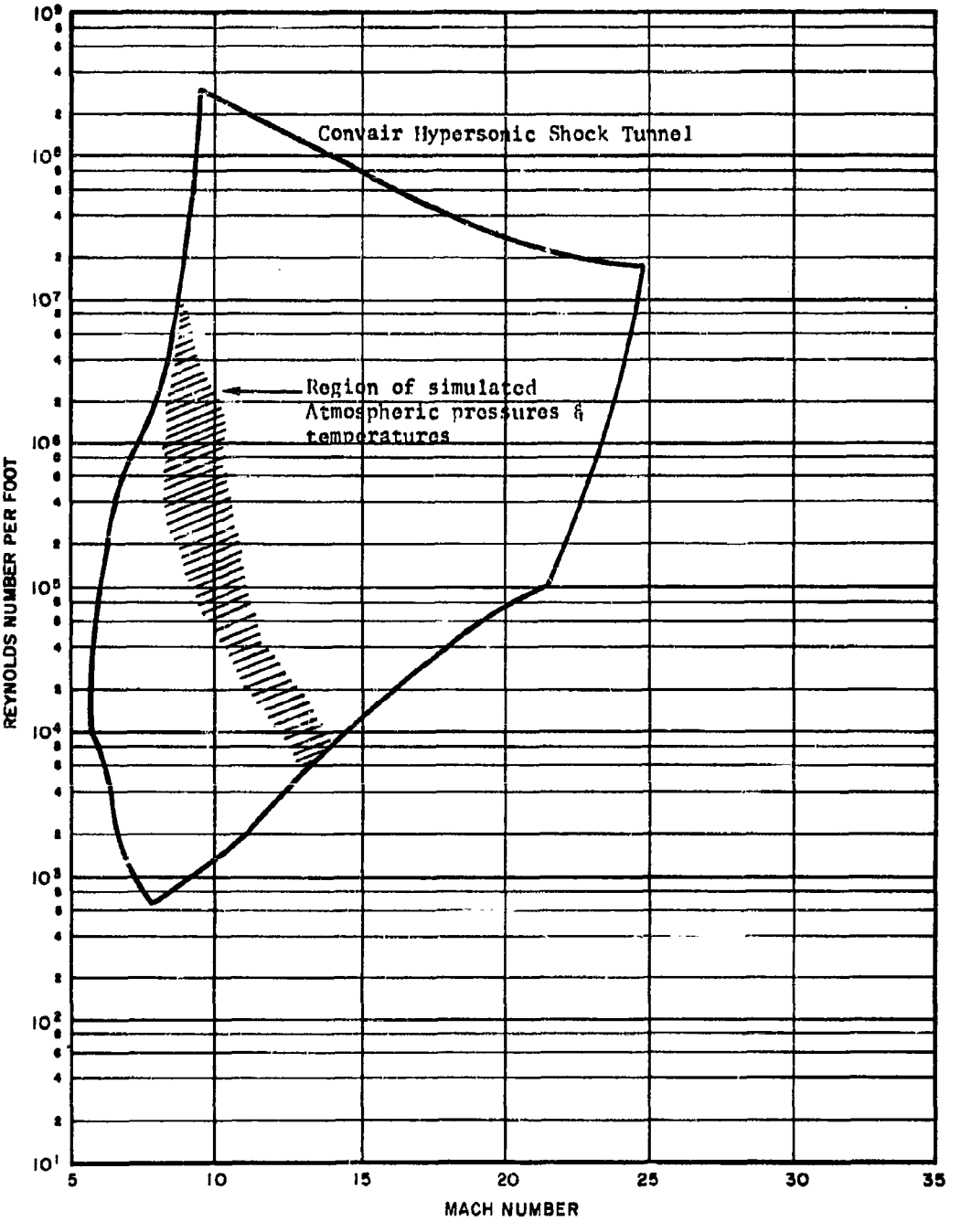
References

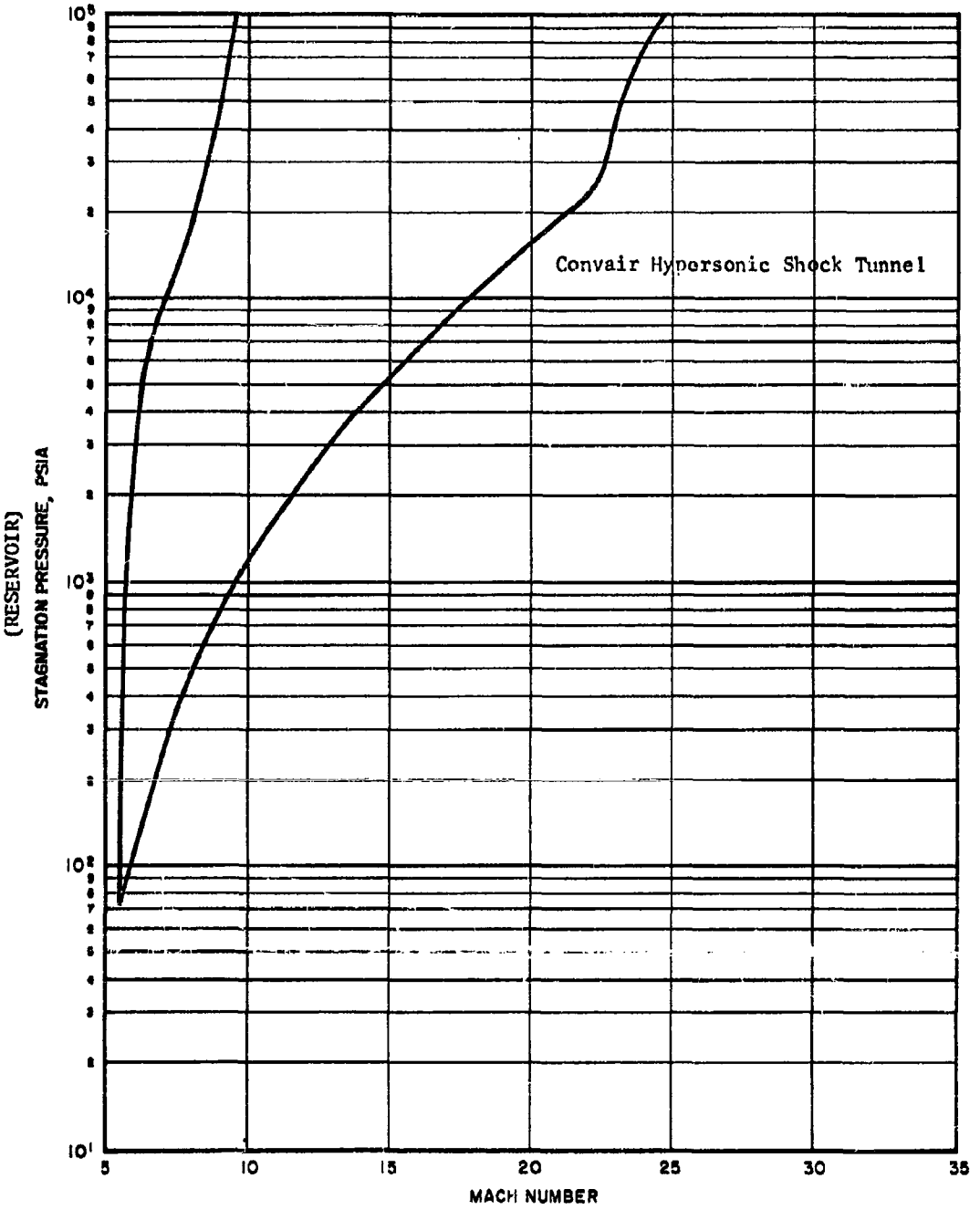
1. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, dated April 1960.

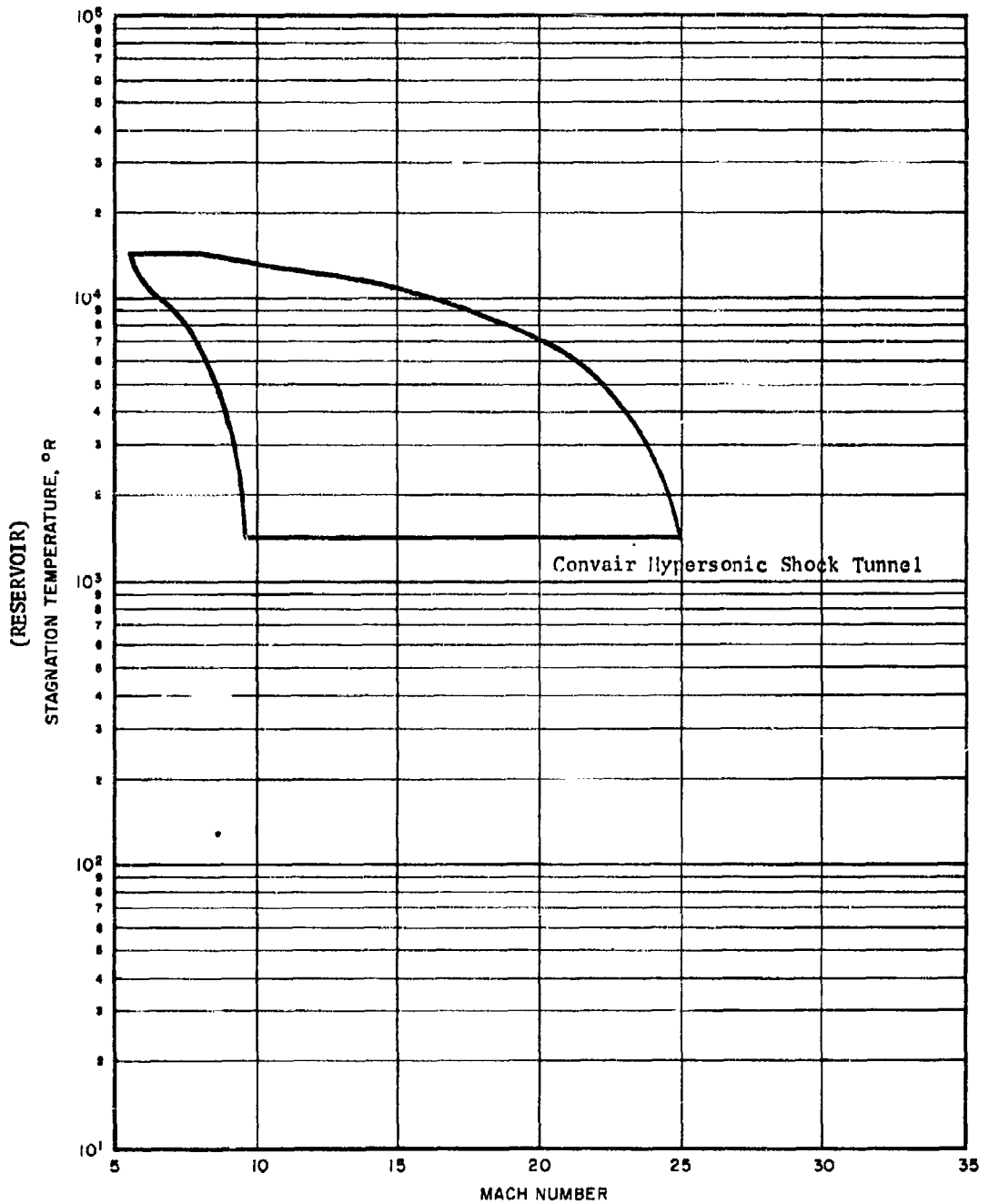
2. "Development of a Combustion Driven Shock Tunnel", by K. C. Hendershot, Convair ERR-SD-057, dated October 1960.

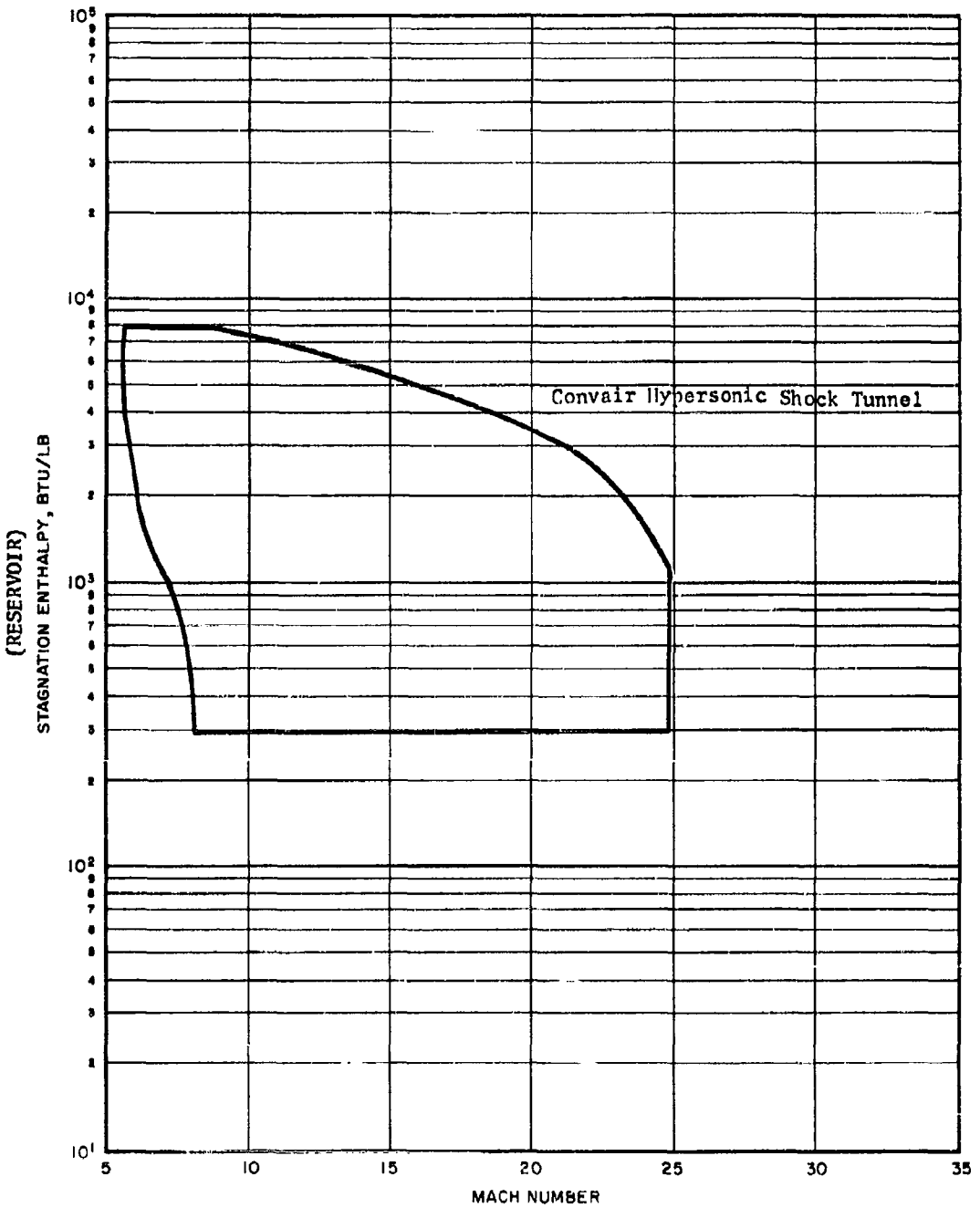
3. "Performance Capability of Hypersonics Laboratory Shock Tunnel", Convair Report No. GDC-62-49, dated March 1962.

4. Letter, D. R. Cumming to N. S. Foy, Convair letter number 6-268, dated 8 February 1963.


Convair Hypersonic Shock Tunnel
Region of simulated
Atmospheric pressures &
temperatures
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


Convair Hypersonic Shock Tunnel
STAGNATION PRESSURE, PSIA (RESERVOIR)
MACH NUMBER
5
10
15
20
25
30
35


STAGNATION TEMPERATURE, °R
(RESERVOIR)
MACH NUMBER
Convair Hypersonic Shock Tunnel
5
10
15
20
25
30
35


Convair Hypersonic Shock Tunnel
(RESERVOIR) STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

30 Inch Shock Tunnel
General Electric Company, MSD
Space Sciences Laboratory
Space Technology Center
Valley Forge, Pennsylvania

Person Responsible

Dr. W. R. Warren

Type

The 30 inch Shock Tunnel is of the combustion driven shock tunnel type. Also available and operational are two smaller shock tunnels with combustion drivers.

Nozzle and Test Section

The 30 inch Shock Tunnel utilizes a conical nozzle expanding to a 30 inch diameter test section. The smaller tunnels are known as the 2"-10" Shock Tunnel and the 2"-30" Shock Tunnel. Numbers refer to driven tube diameter and nozzle exit diameter respectively.

Instrumentation and Test Capability

Force moment, pressure, heat transfer, flow visualization and flow interaction with magnetic and electric fields may be tested in this facility.

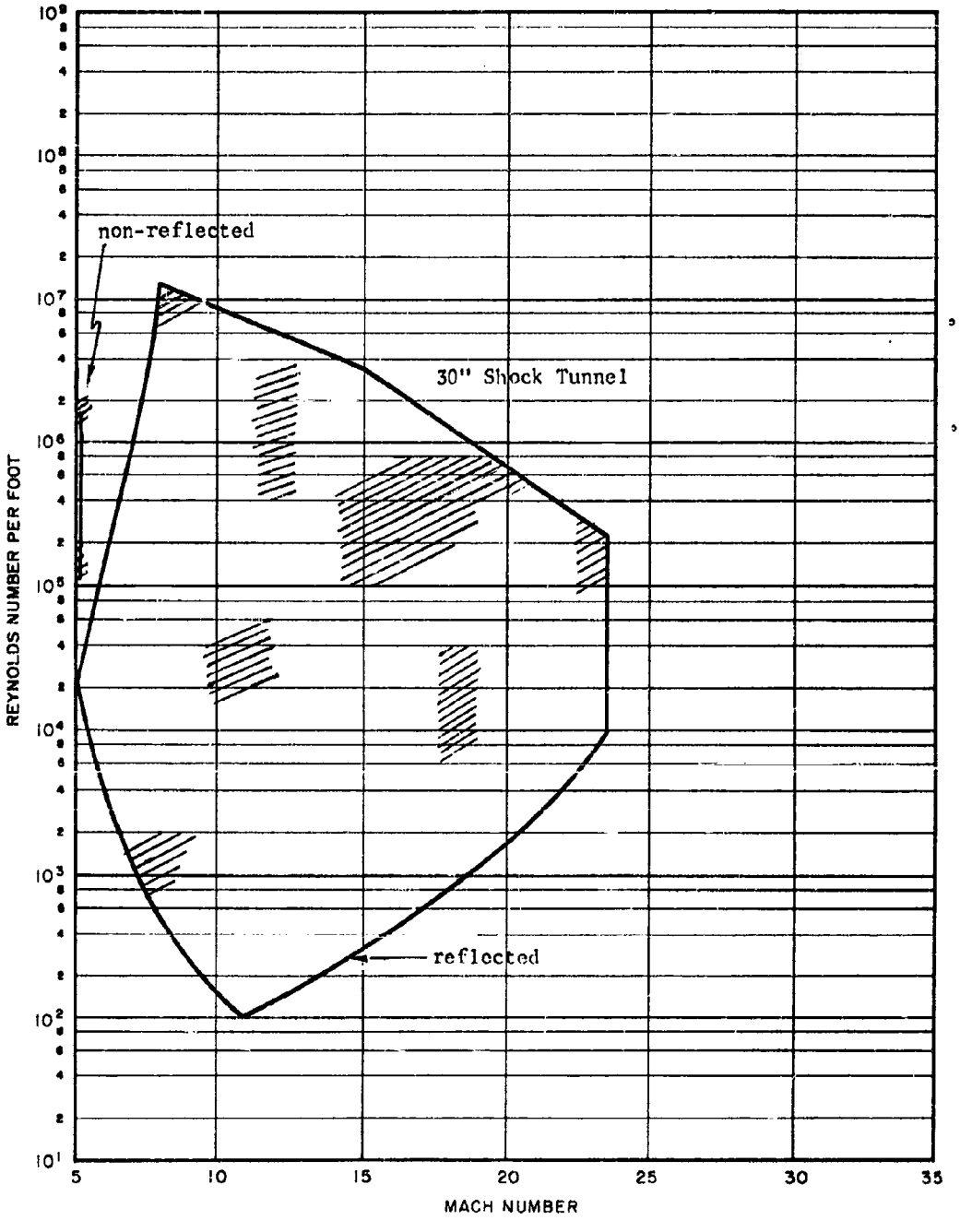
Running Time

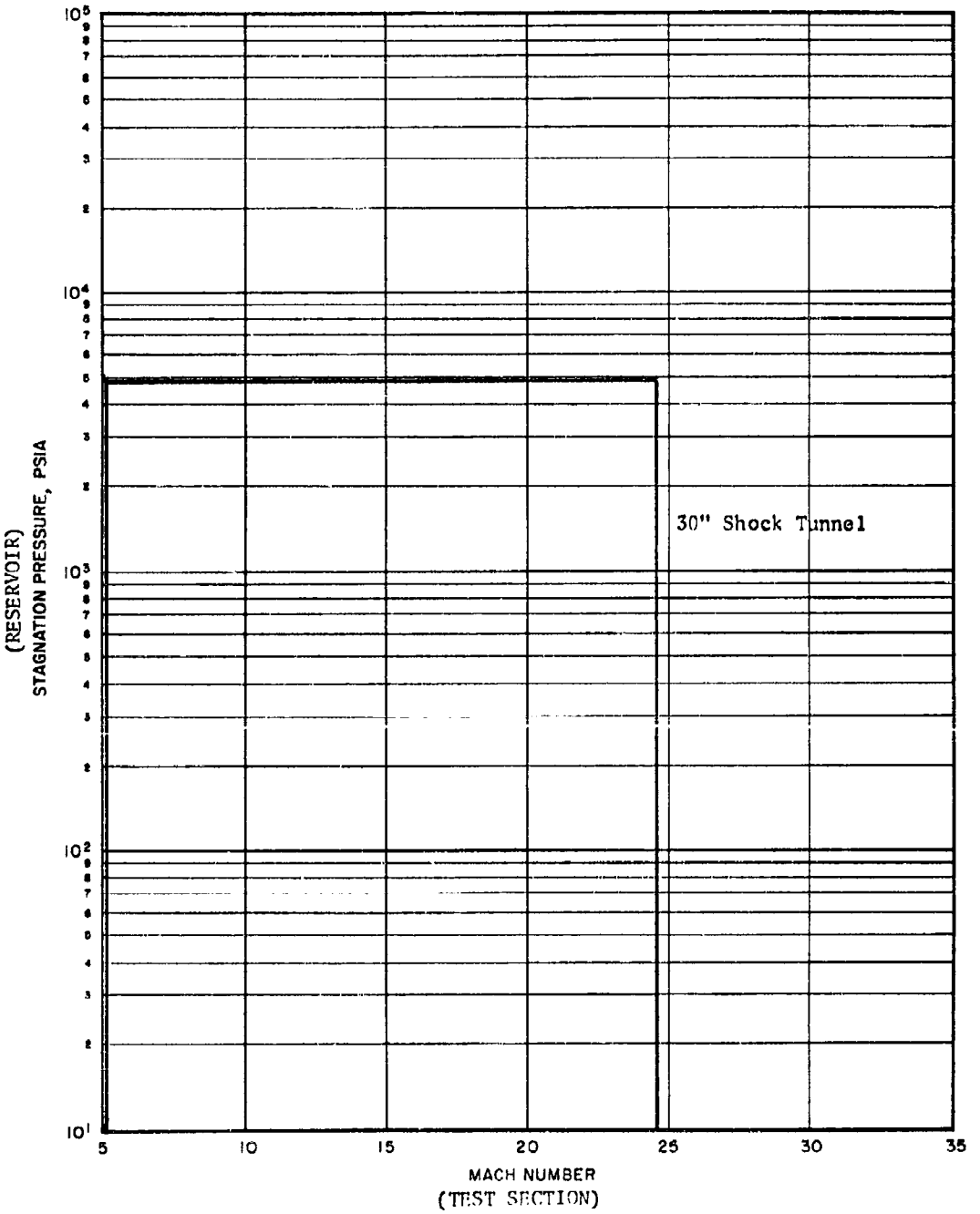
Running times are on the order of one to five milliseconds.

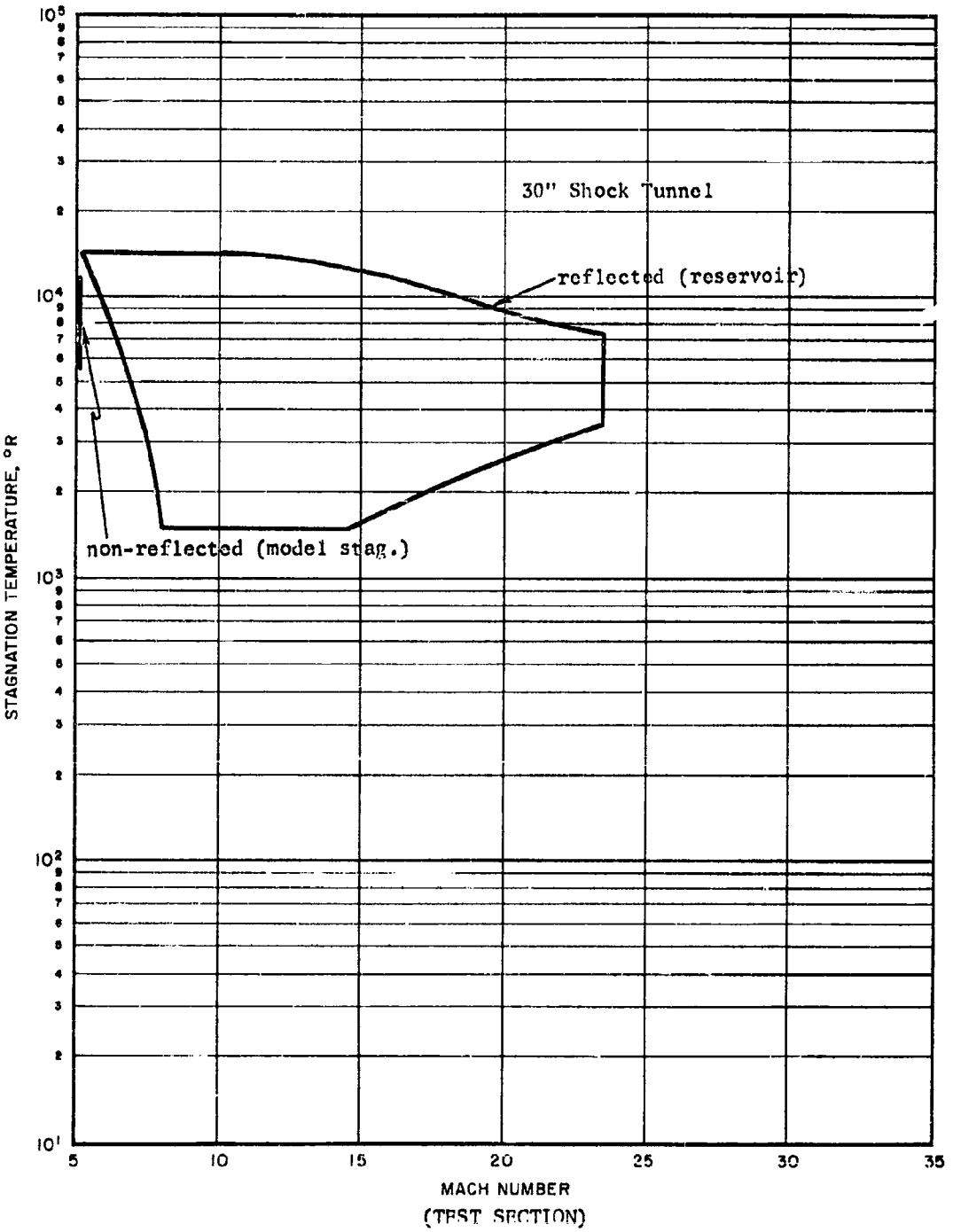
References

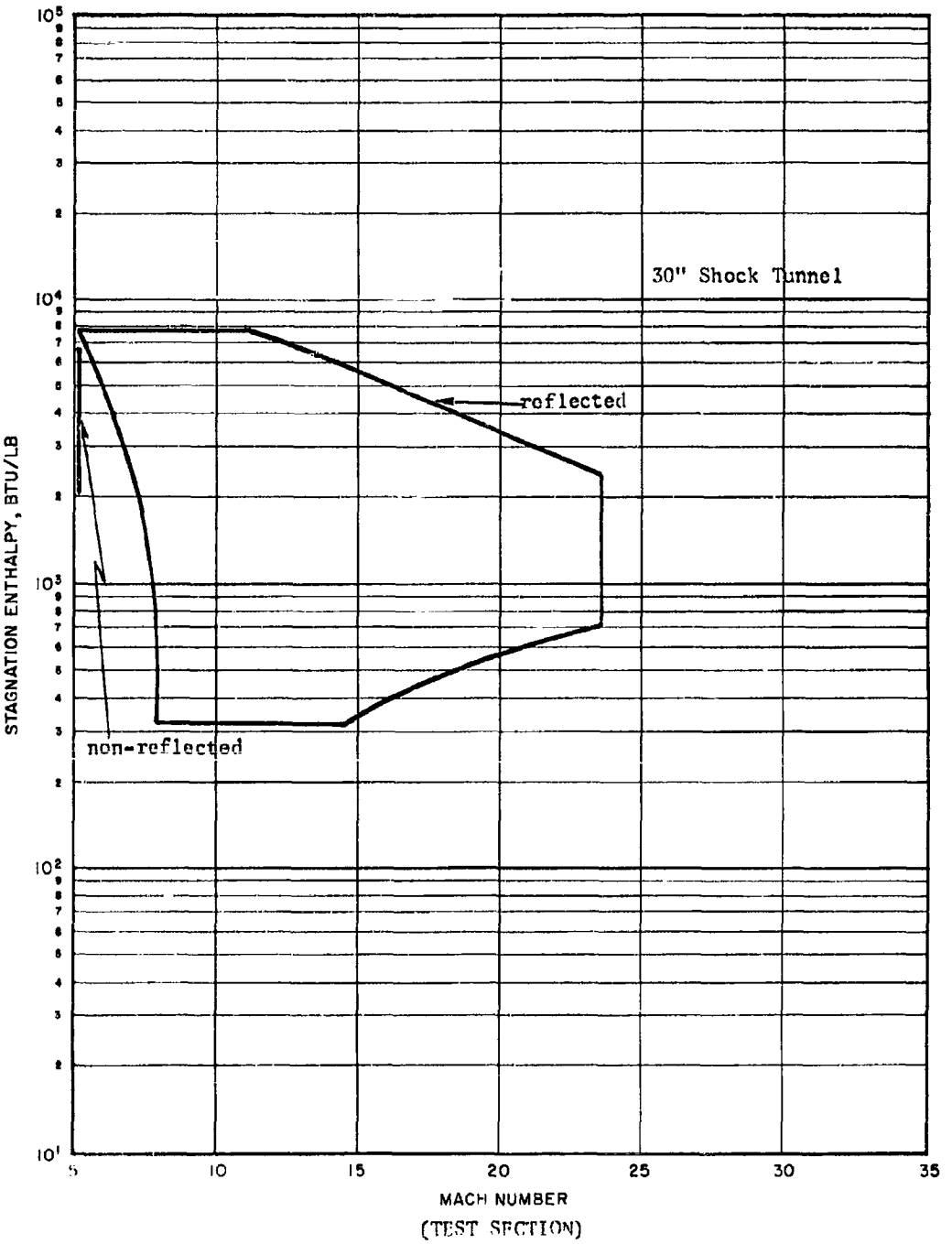
1. "The Capabilities of the Shock Tunnel in the Study of the Aerodynamics of Atmospheric Entry," E. M. Kaegi et. al.

2. Letter, C. J. Harris to N. S. Foy, dated 19 December 1962.


non-reflected
30" Shock Tunnel
reflected
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


(RESERVOIR)
STAGNATION PRESSURE, PSIA
10^5
10^4
10^3
10^2
10^1
30" Shock Tunnel
5
10
15
20
25
30
35
MACH NUMBER
(TEST SECTION)


30" Shock Tunnel
reflected (reservoir)
non-reflected (model stag.)
STAGNATION TEMPERATURE, °R
MACH NUMBER
(TEST SECTION)
5
10
15
20
25
30
35


30" Shock Tunnel
reflected
non-reflected
STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
(TEST SECTION)
5
10
15
20
25
30
35

Name of Facility

Grumman Hypersonic Shock Tunnel
Grumman Aircraft Engineering Corporation
Bethpage, Long Island, New York

Person Responsible

Richard A. Scheuing, Assistant Chief of Research

Type

The Grumman Hypersonic Shock Tunnel is of the combustion driven shock tunnel type.

Nozzle and Test Section

The shock tunnel has a 25° total angle conical nozzle with an 18 inch exit diameter. It utilizes a 20 inch square test section at the forward end of a 15 foot long dump tank. A contoured nozzle is under design. Blunt models are limited to about 4 inches diameter, and flat models are limited to about 6 inches span. The tunnel has viewing windows one foot square.

Instrumentation and Test Capabilities

20 channels of recording instrumentation are available for pressure and heat transfer data. High speed motion picture or still Schlieren and glow photographs may be obtained in color or black and white.

Running Time

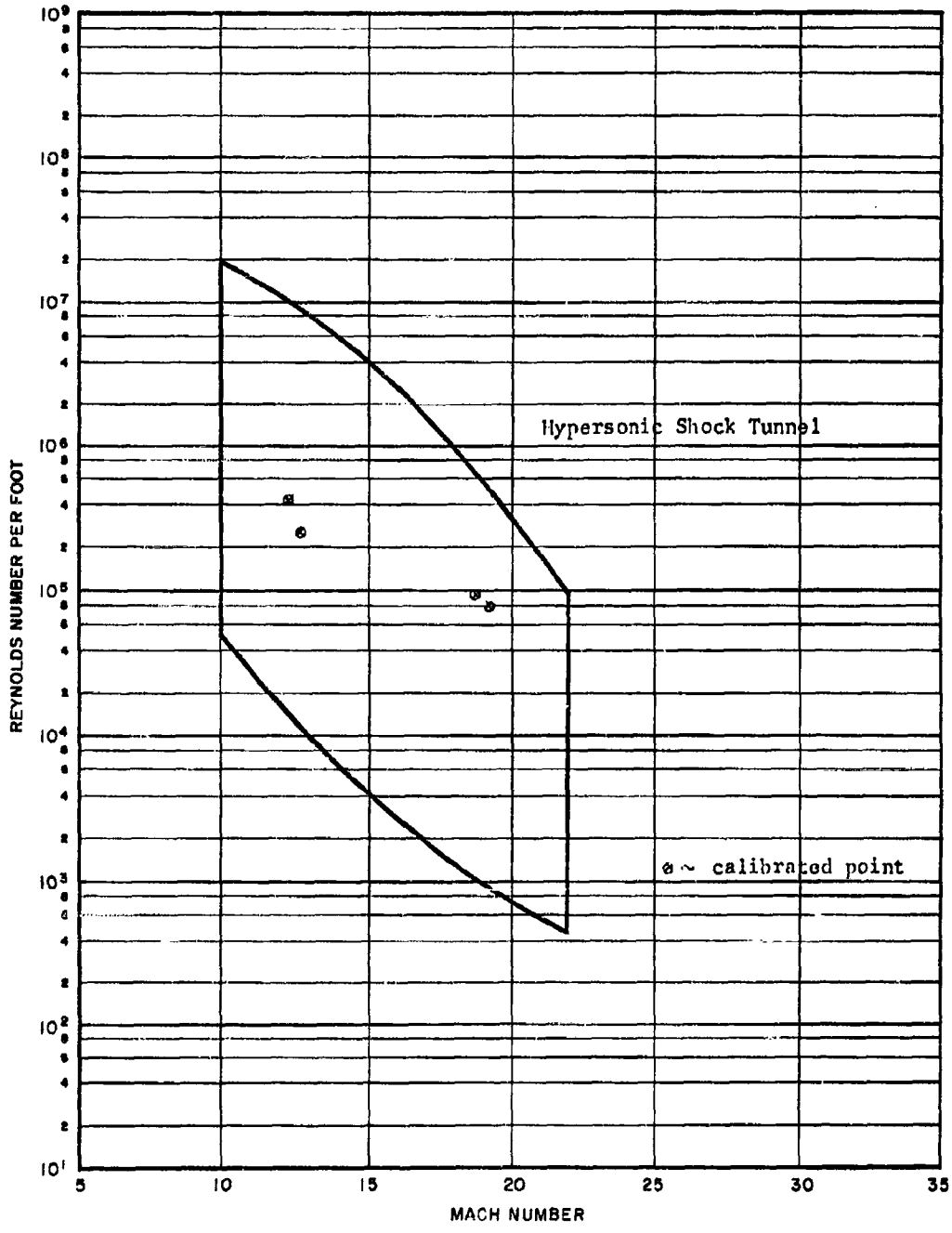
Running times in this facility are on the order of 2 to 4 milliseconds.

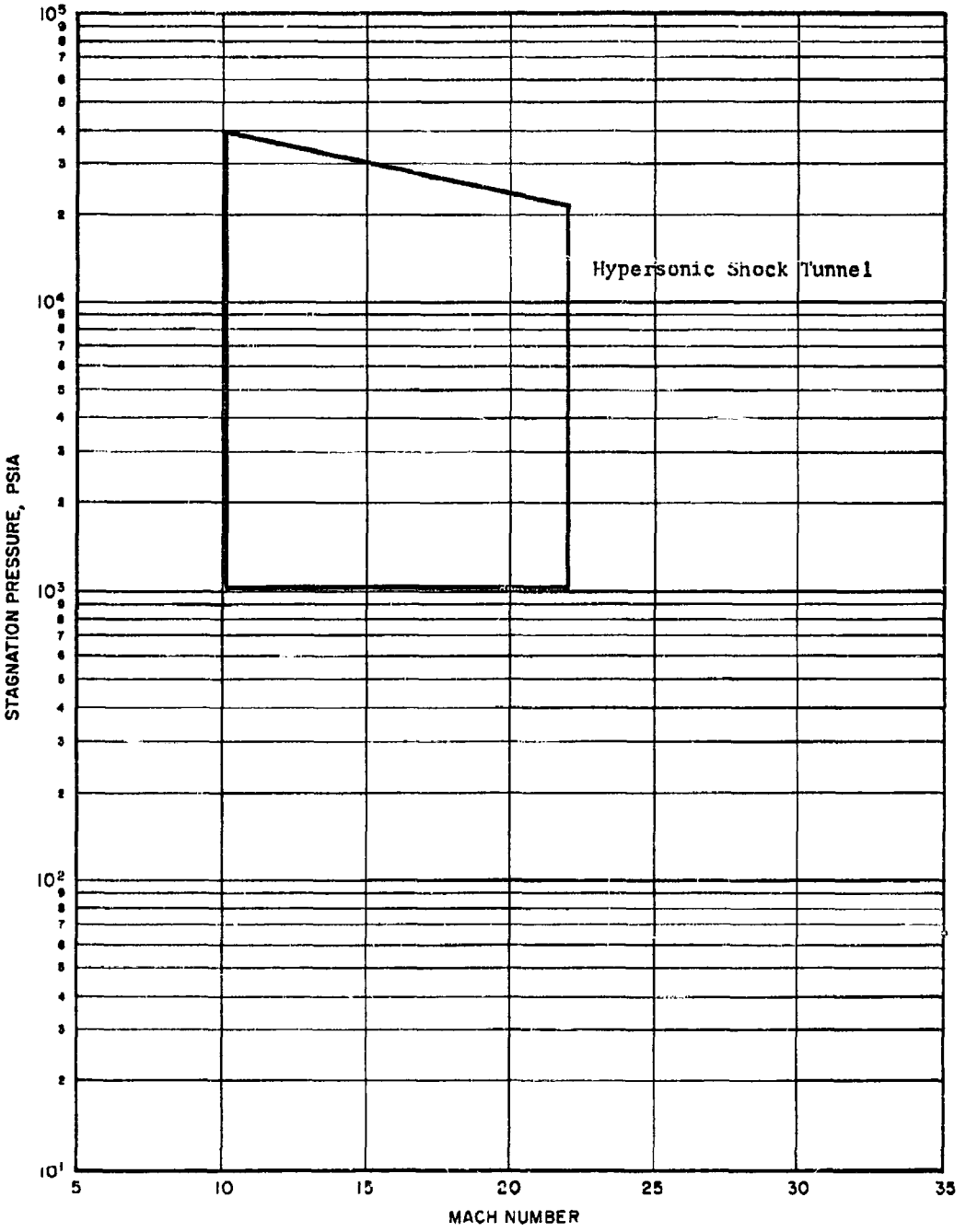
References

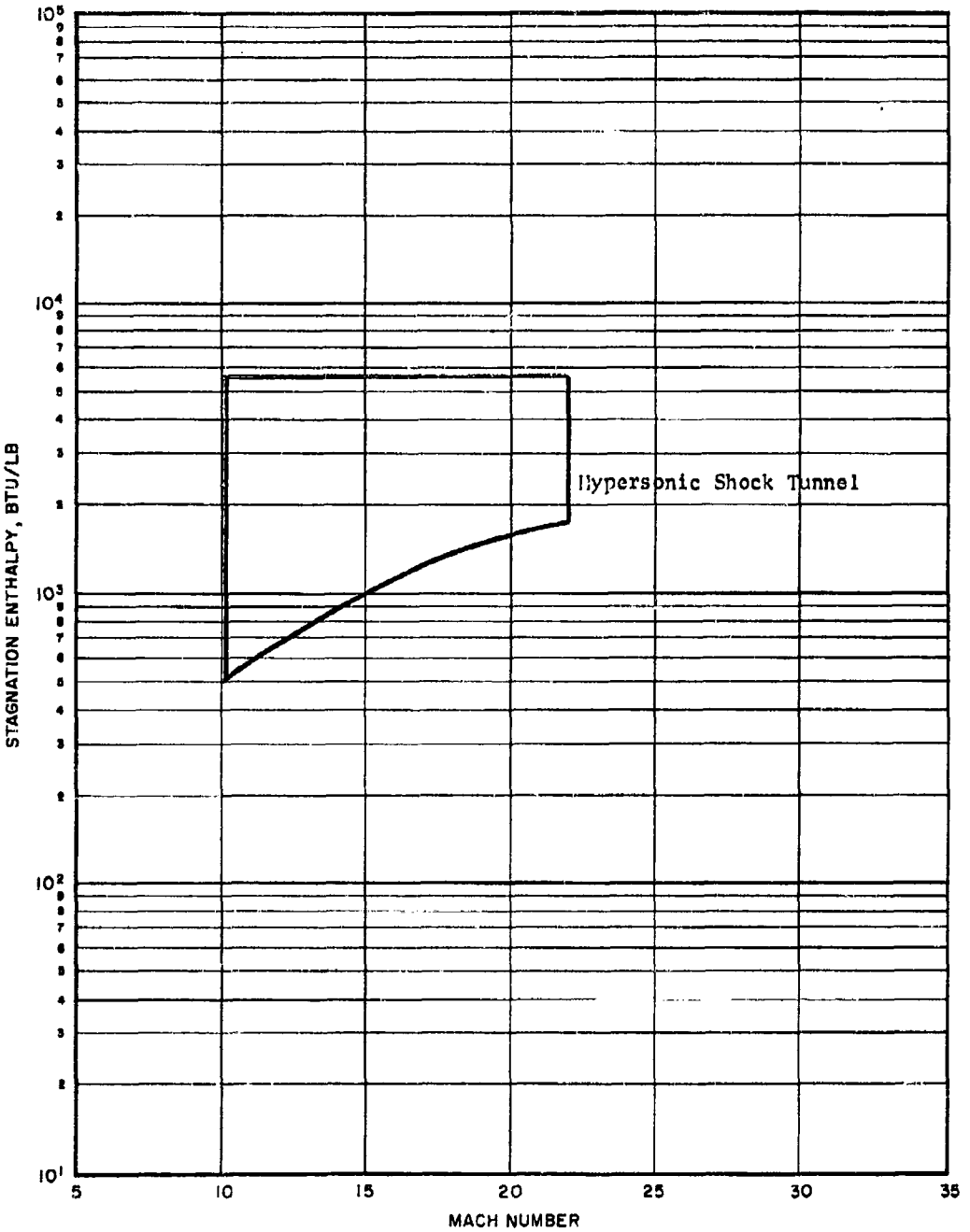
1. Letter, Richard A. Scheuing to Dr. S. T. Chu, dated 17 September 1962.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States," Boeing Report No. D2-5785, dated April 1960.

3. Letter, Richard A. Scheuing to N. S. Foy, dated 7 January 1963.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hypersonic Shock Tunnel
⊘ ~ calibrated point


STAGNATION PRESSURE, PSIA
MACH NUMBER
Hypersonic Shock Tunnel
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


STAGNATION ENTHALPY, BTU/LB
10^5
10^4
10^3
10^2
10^1
Hypersonic Shock Tunnel
5
10
15
20
25
30
35
MACH NUMBER

Name of Facility

JPL 21 Inch Hypersonic Wind Tunnel
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Person Responsible

Robert E. Covey, Chief
Aerodynamic Facilities Section

Type

The 21 inch hypersonic wind tunnel is of the continuous variable density type.

Nozzle and Test Section

The hypersonic tunnel uses a variable geometry two-dimensional nozzle which expands the flow into a test section which is 21 inches wide and 15 to 28 inches high (adjustable). The Mach number range is from 4 to 11.

Instrumentation and Test Capabilities

Force, pressure and heat transfer measurements may be made at this facility, using "standard" techniques. It is also possible to vary the model wall temperature; measure dynamic stability and observe wake shapes by the use of a free-flight technique; and measure dynamic stability by mounting the model on a gas bearing or ball bearing support.

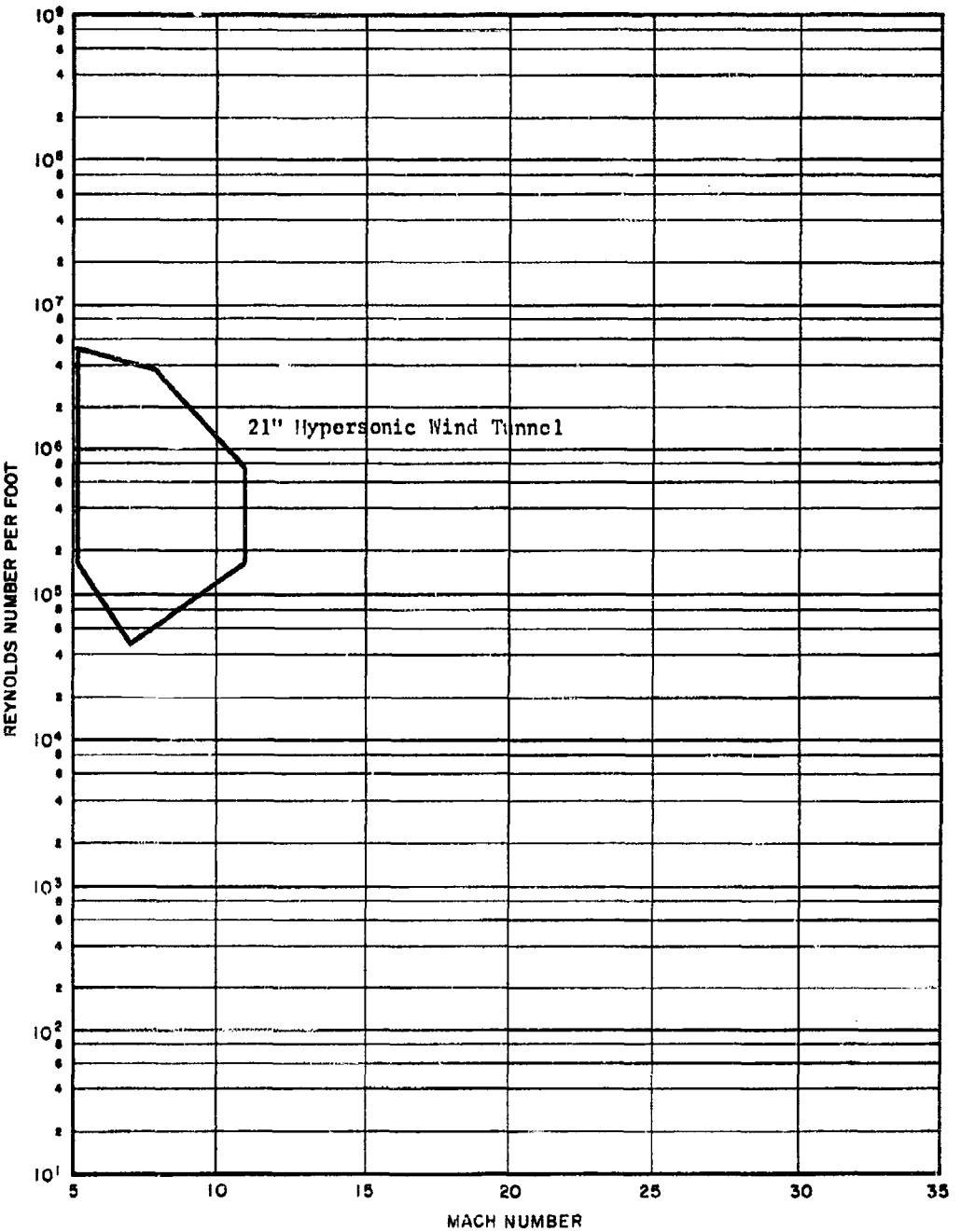
Running Time

Running time is unrestricted, although shutdown is necessary while adjusting nozzle to a different Mach number. Nozzle shape change requires about one hour, and is usually scheduled to occur during an off-shift devoted to long model changes, air-off calibrations, etc.

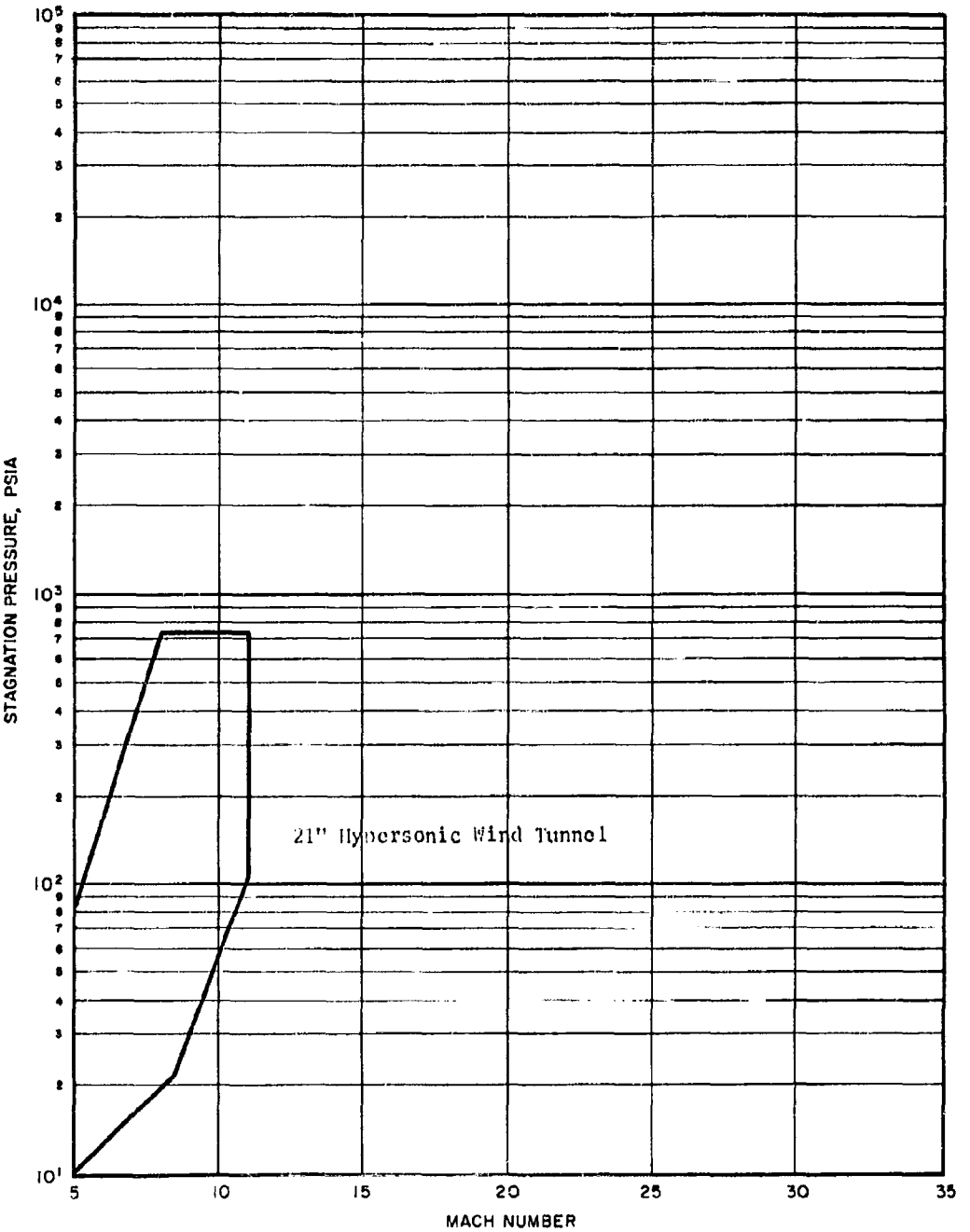
References

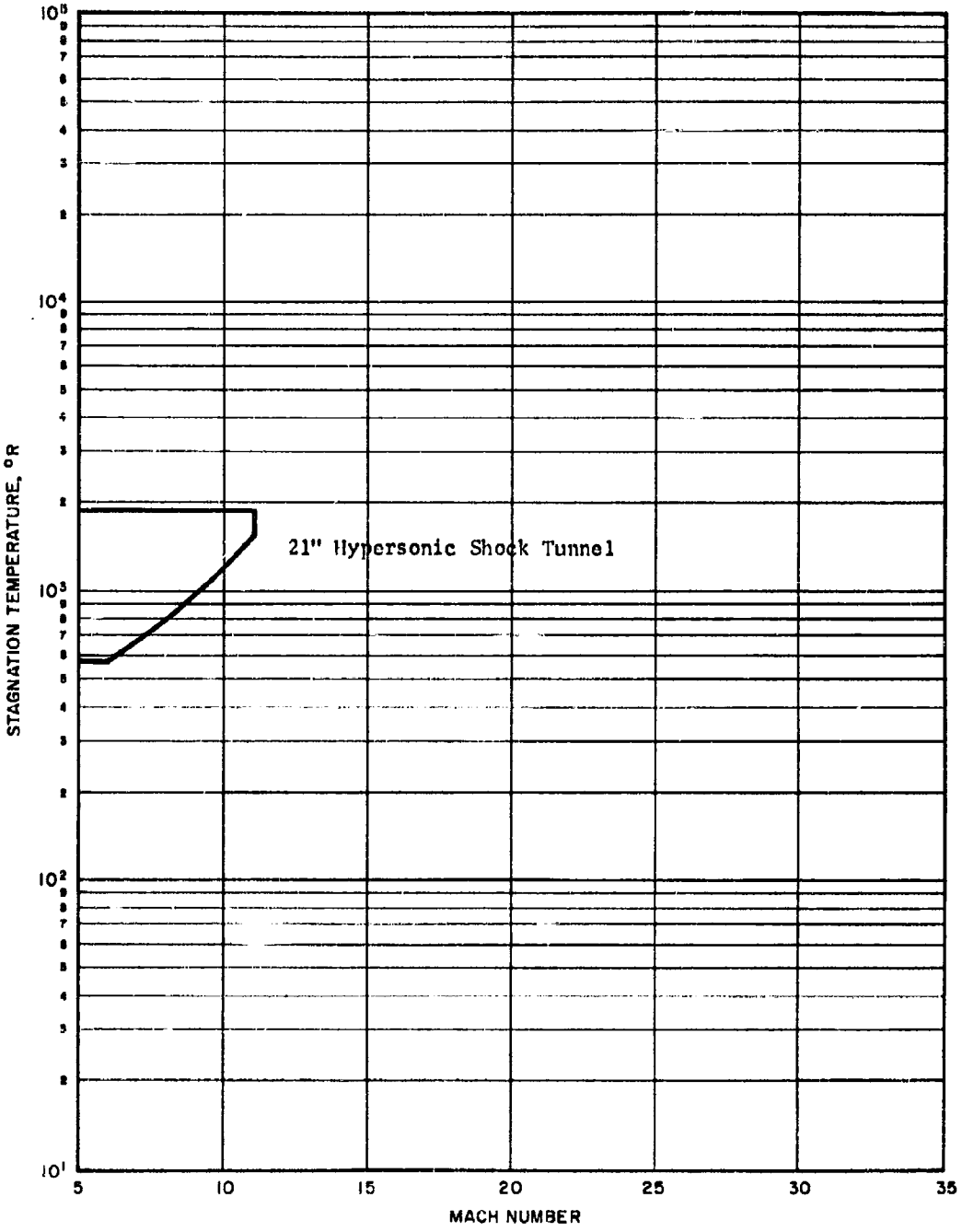
1. "Wind Tunnel Facilities at the Jet Propulsion Laboratory," JPL Technical Release No. 34-257, revised 1 January 1962.

2. Letter, R. E. Covey to N. S. Foy, dated 20 December 1962.


21" Hypersonic Wind Tunnel
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35

JET PROPULSION LABORATORY




STAGNATION TEMPERATURE, °R
21" Hypersonic Shock Tunnel
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

Lockheed Missiles and Space Company
3251 Hanover Street
Palo Alto, California

Person Responsible

D. Bershader, Manager, Gas Dynamics

Type

Two hypersonic facilities are presently operational at LMSC. They are:

A) The 3 Inch Shock Tunnel

B) The Spark Heated Tunnel, which is of the hotshot type.

Nozzle and Test Section

A) The 3 Inch Shock Tunnel utilizes a conical nozzle and a 5 inch diameter test section. It has a 3 inch diameter test core, and can accommodate a 1 inch diameter model. A 20 inch diameter nozzle will be available in June 1963.

B) The Spark Heated Tunnel has a conical nozzle with semi-angle of 8.9° with tungsten throat inserts of .050 to .200 inch diameter. The test section is 24 inches in diameter, with one pair of 12 inch diameter windows, four ports for sting support and electrical connections to instrumentation. The test core is approximately 10 inches in diameter.

Instrumentation and Test Capabilities

Pressure, temperature and force can be measured in these facilities. Thick film and thin film heat transfer gauges are available. Data reduction is manual.

Running Times

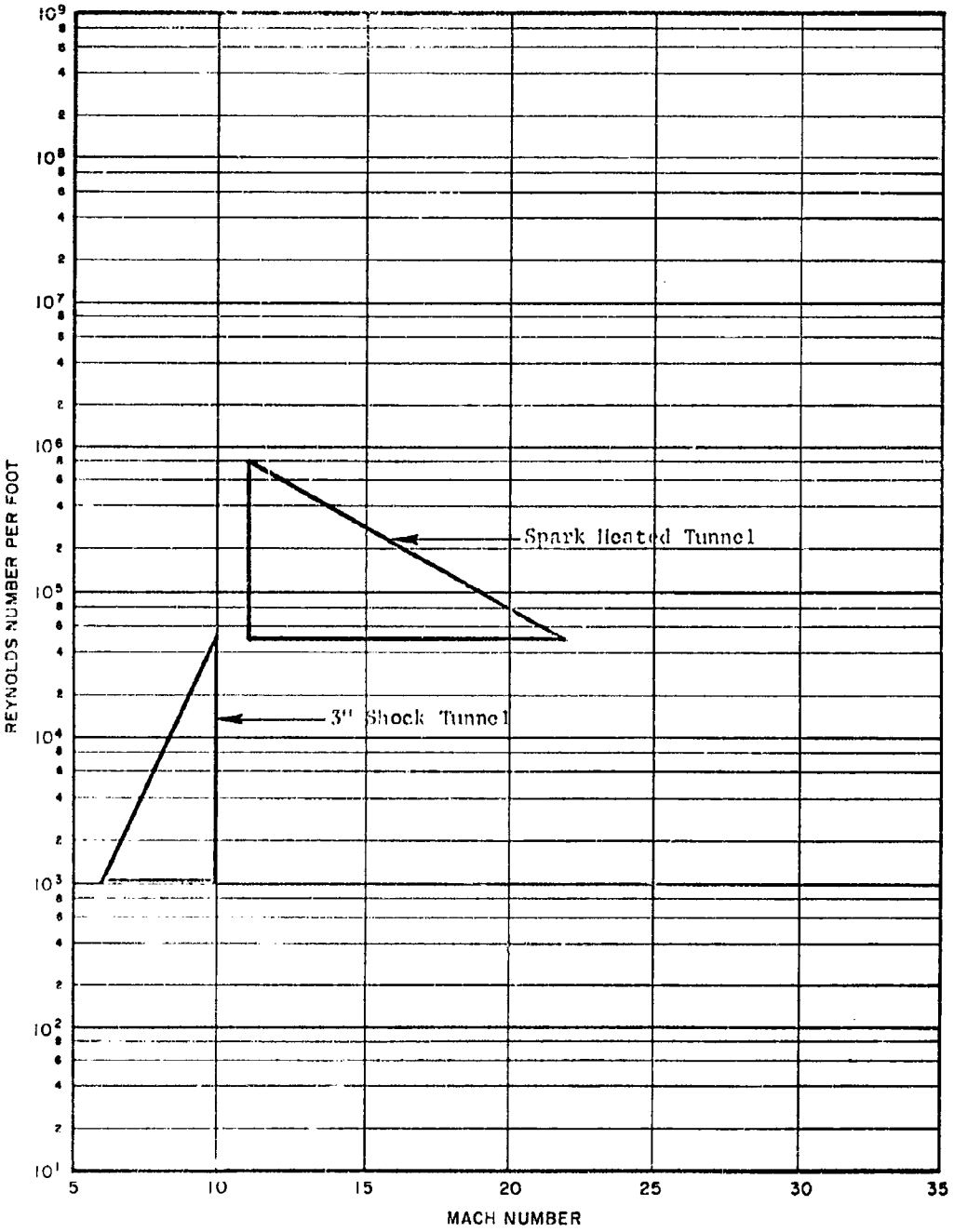
A) 3 Inch Shock Tunnel - 2 to 3 milliseconds

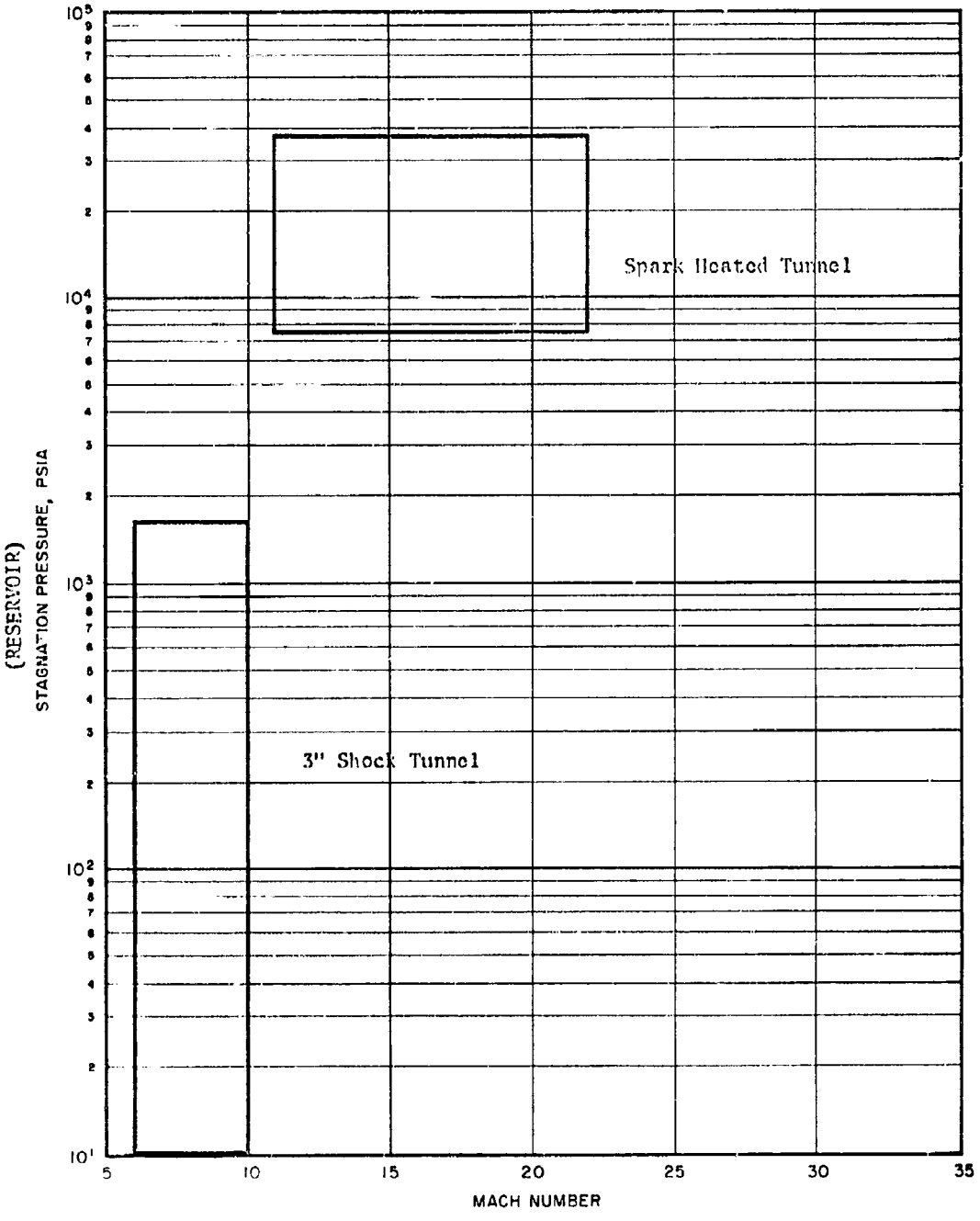
B) Spark Heated Tunnel - 25 milliseconds

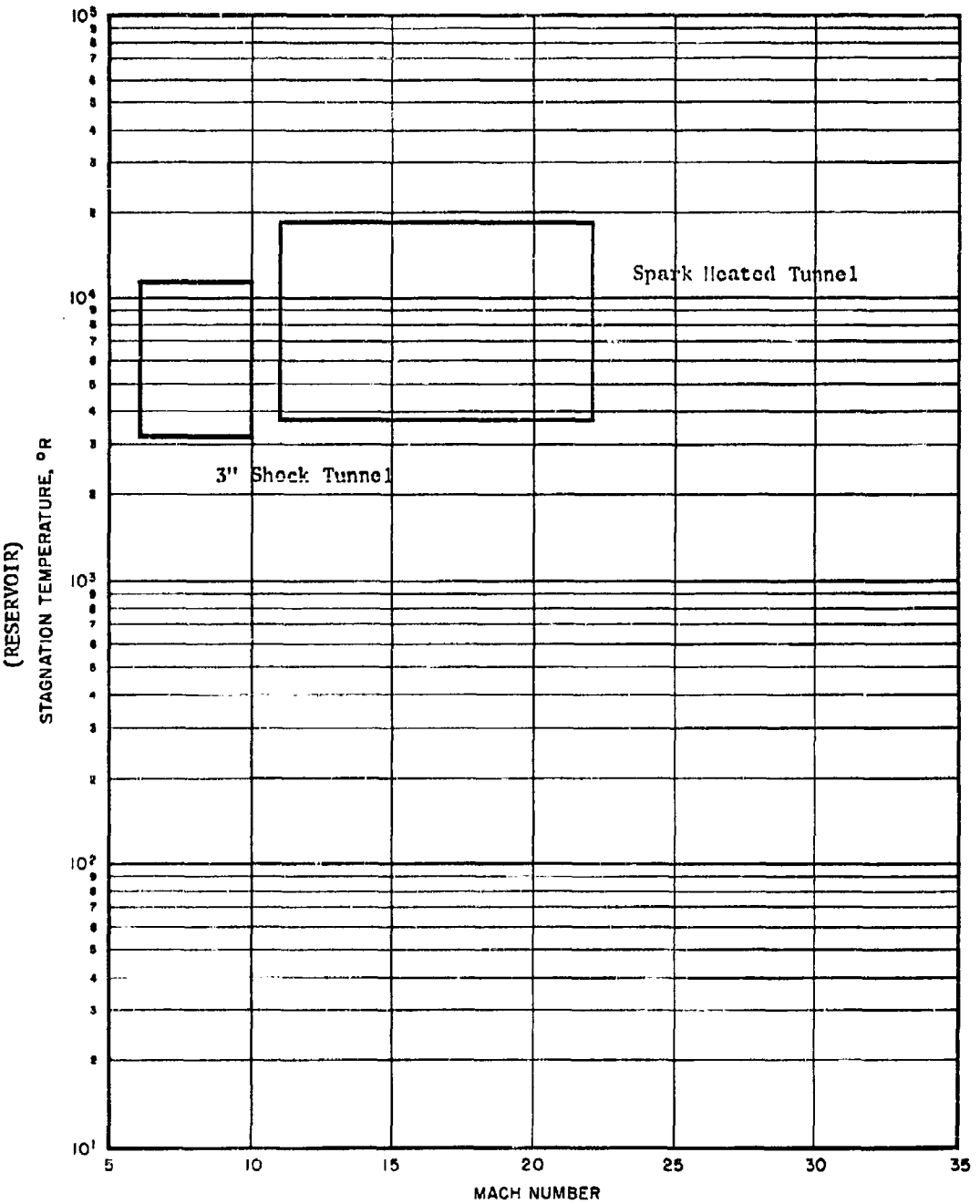
References

1. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.

2. Telephone conversation with H. Hoshizaki, 1 March 1963.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Spark Heated Tunnel
3" Shock Tunnel
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


Spark Heated Tunnel
3" Shock Tunnel
(RESERVOIR) STAGNATION PRESSURE, PSIA
MACH NUMBER
5
10
15
20
25
30
35


Spark Heated Tunnel
3" Shock Tunnel
(RESERVOIR) STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

Hotshot Wind Tunnel
Martin-Marietta Corporation
Space Systems Division
Baltimore 3, Maryland

Person Responsible

Mr. Lewis G. Cooper
Supervisor, Experimental Fluid Mechanics Section

Type

The Martin facility is of the arc-driven hotshot type, using nitrogen as the test gas.

Nozzle and Test Section

A conical nozzle is used to expand the flow. A 12 inch diameter test core results at M = 18, and an 8 inch diameter test core results at M = 22.

Instrumentation and Test Capabilities

Several programs involving force and pressure data have been run in this facility. Calibrations exist at M = 18.8, 22.5 and 24.2.

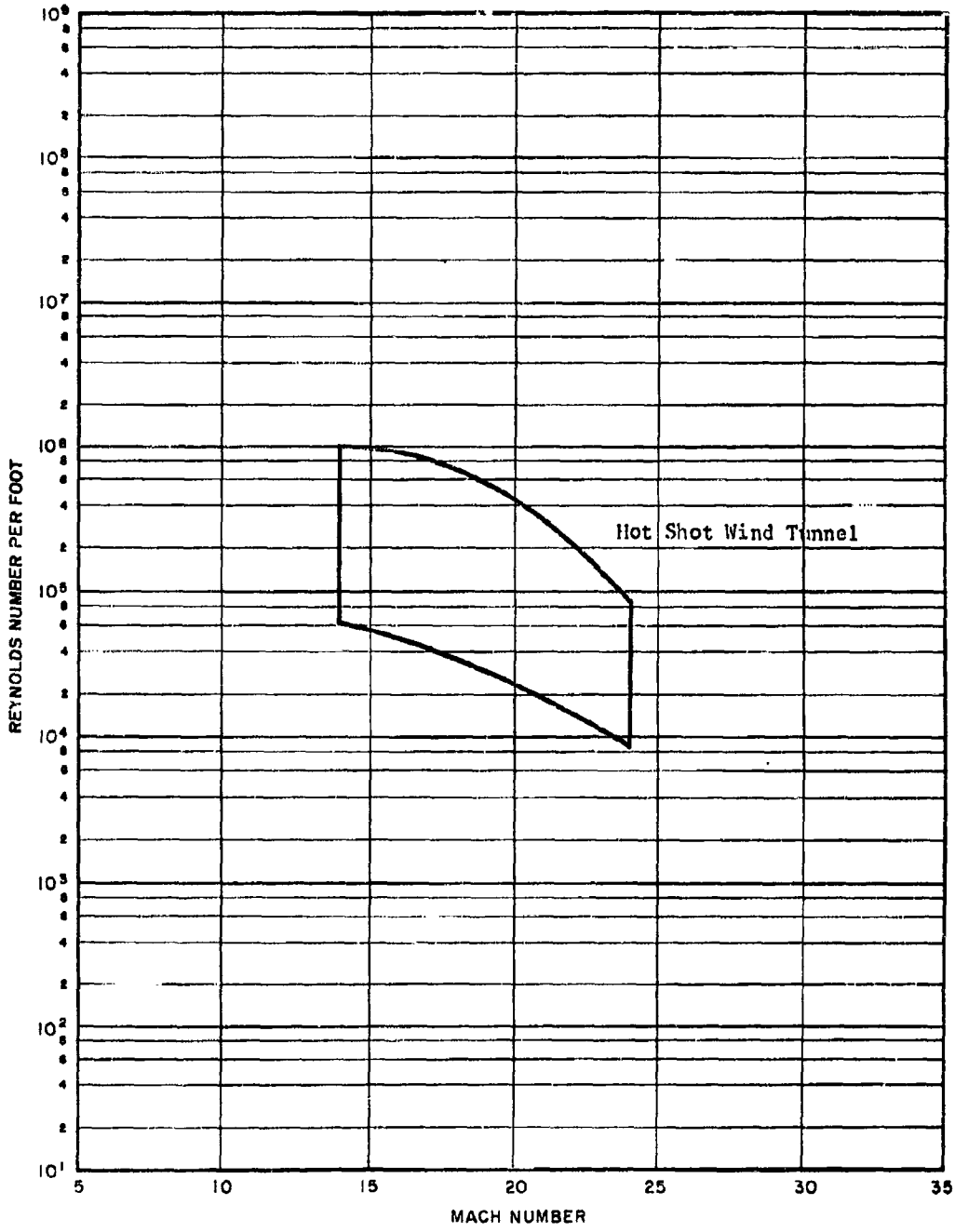
Running Time

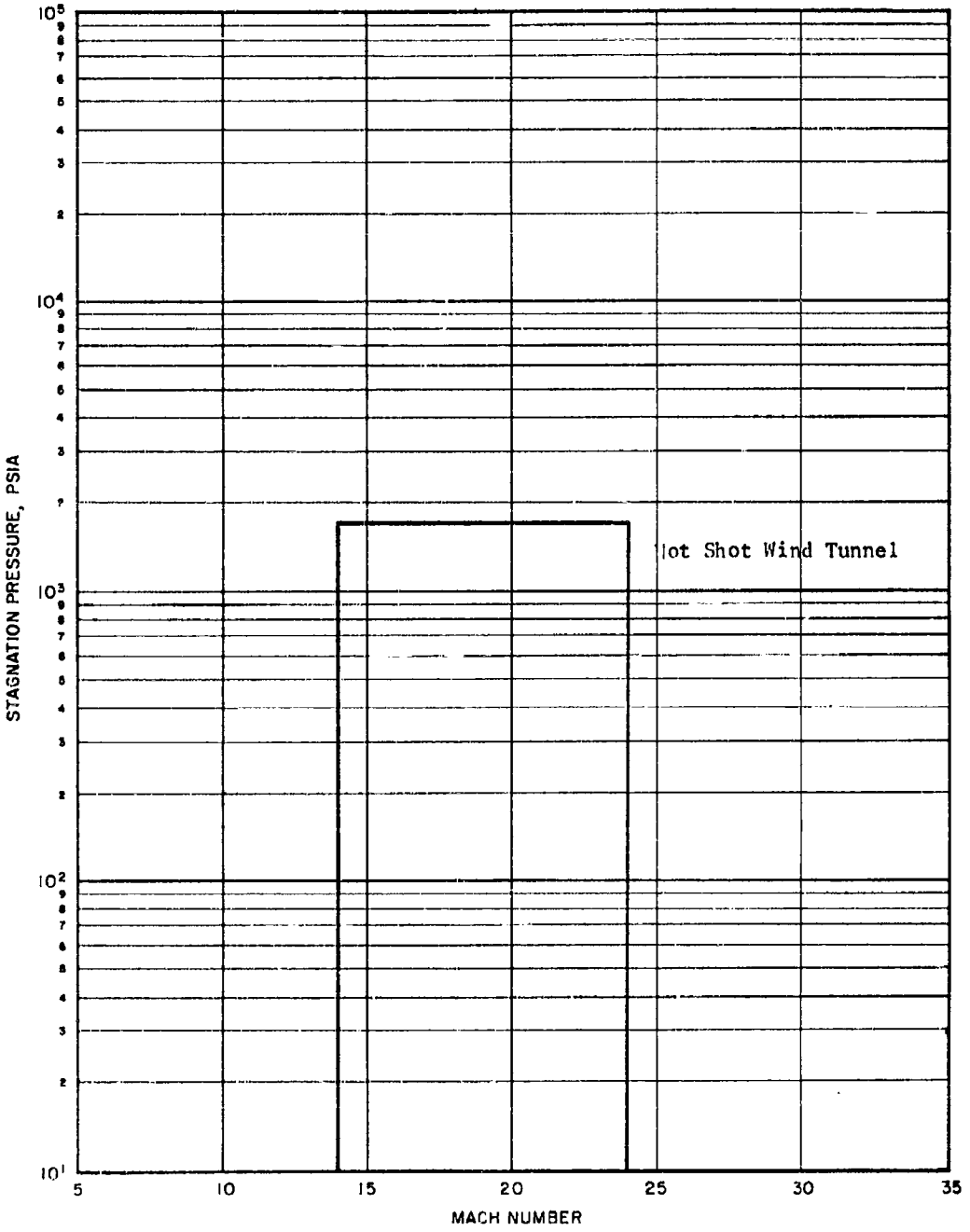
Running times for the Martin hotshot facility are on the order of 60 to 100 milliseconds.

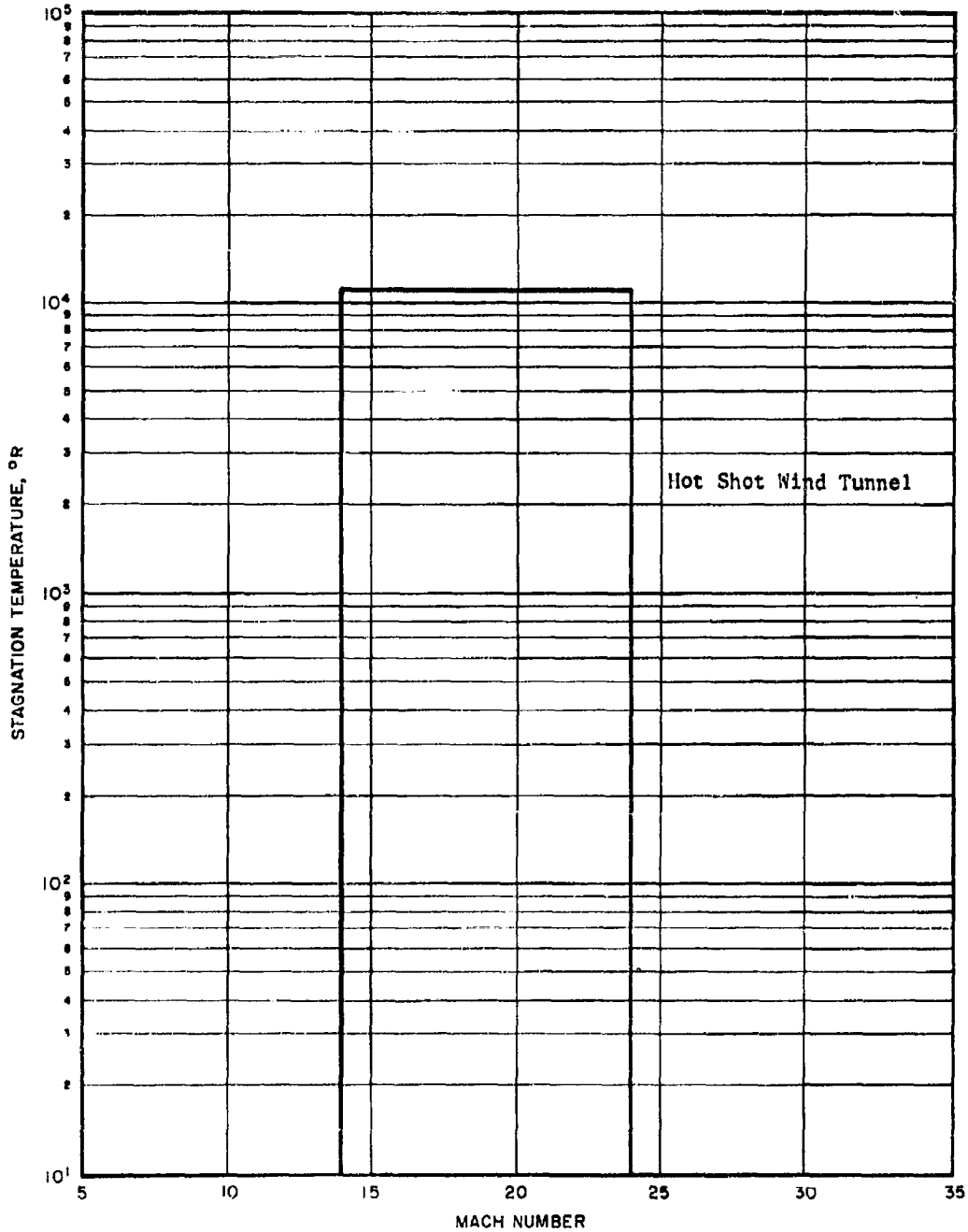
Reference

1. Brochure, "Correlation Data from the Martin Baltimore Hot Shot Wind Tunnel."

2. Letter, L. G. Cooper to N. S. Foy, dated 8 January 1963, with enclosures.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hot Shot Wind Tunnel
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
lot Shot Wind Tunnel


STAGNATION TEMPERATURE, °R
MACH NUMBER
Hot Shot Wind Tunnel
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35

Name of Facility

Aerophysics Laboratory
Massachusetts Institute of Technology
560 Memorial Drive
Cambridge 39, Massachusetts

Person Responsible

Prof. Morton Finston, Director

Type

A) The Gas Dynamic Facility is a continuous open jet wind tunnel with a 4 by 4 inch nozzle.

B) The 18 by 24 inch Wind Tunnel is a M = 7.6 installation, of the continuous type.

Nozzle and Test Section

A) The Gas Dynamic Facility uses a Mach 4.8, two-dimensional nozzle.

B) The 18 by 24 inch Wind Tunnel utilizes a 12 inch diameter nozzle operating inside of an M = 4.0 nozzle, which serves as an ejector.

Instrumentation and Test Capabilities

A) The magnetic suspension and balance system in the Gas Dynamic Facility have made it possible to study flow near the base of a model without support interference.

B) The 18 by 24 inch Wind Tunnel has been used for force tests and pressure distribution tests. MIT has an electronic low pressure manometer system that can handle up to 120 pressure taps.

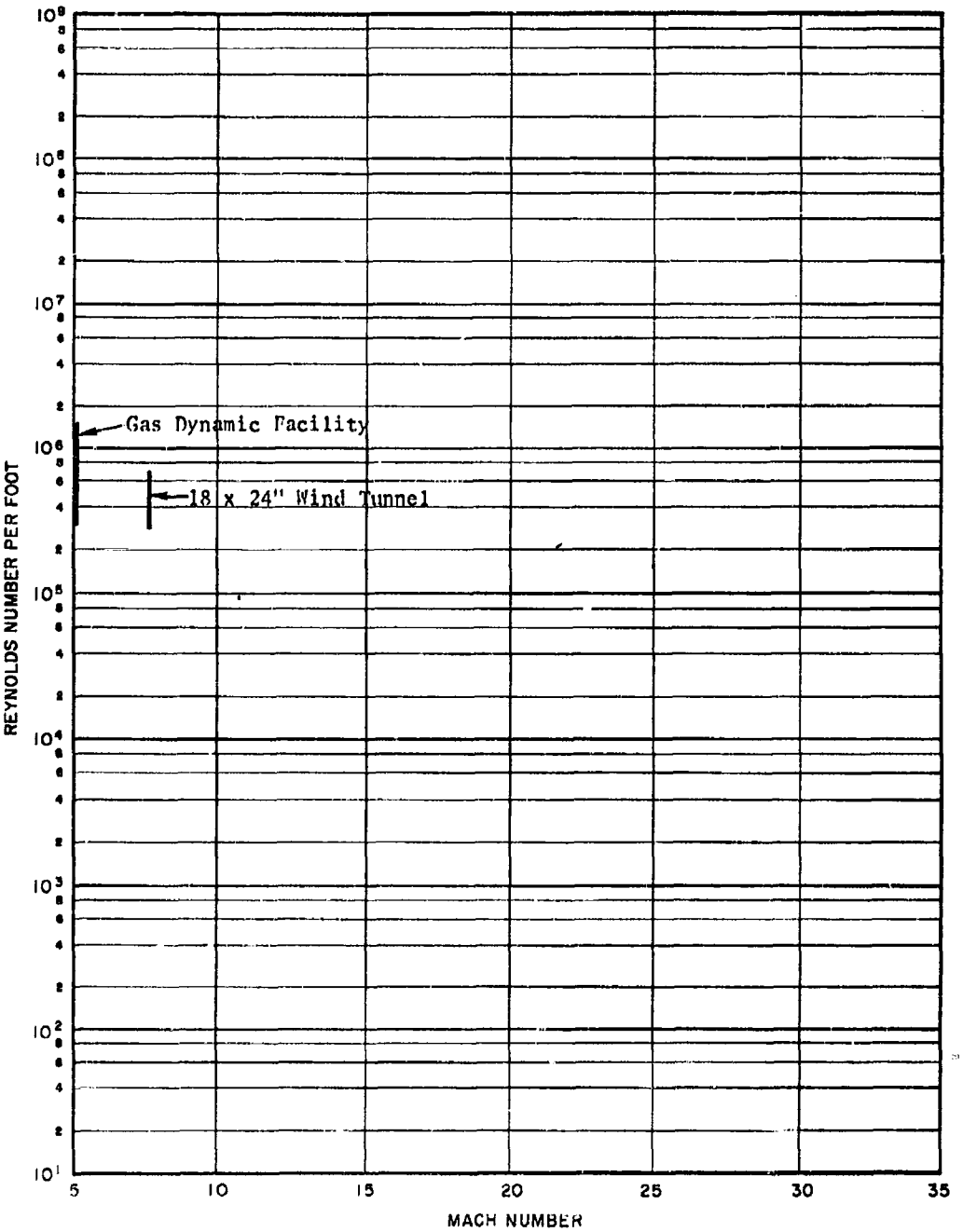
Running Times

Both facilities may be run continuously.

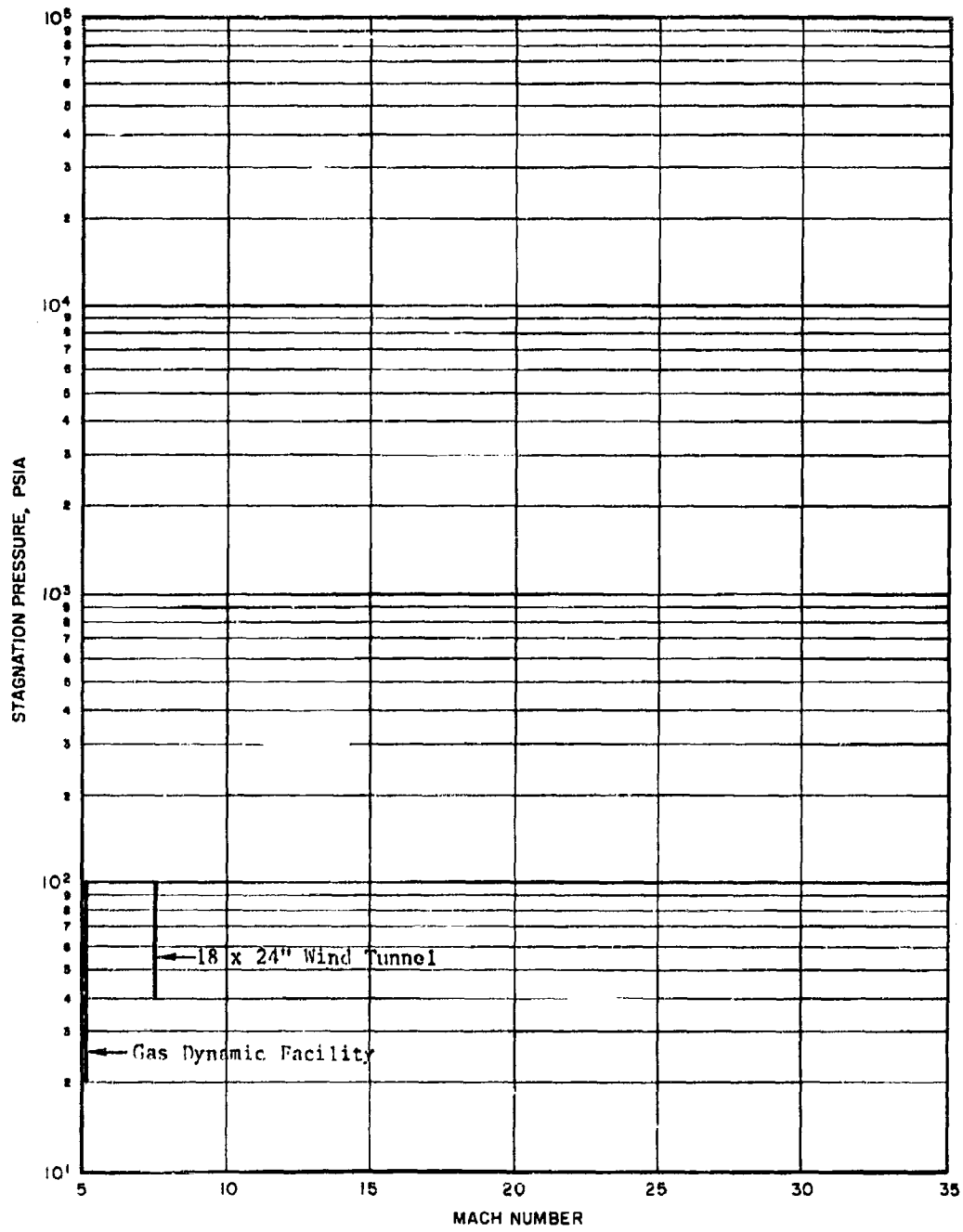
Reference

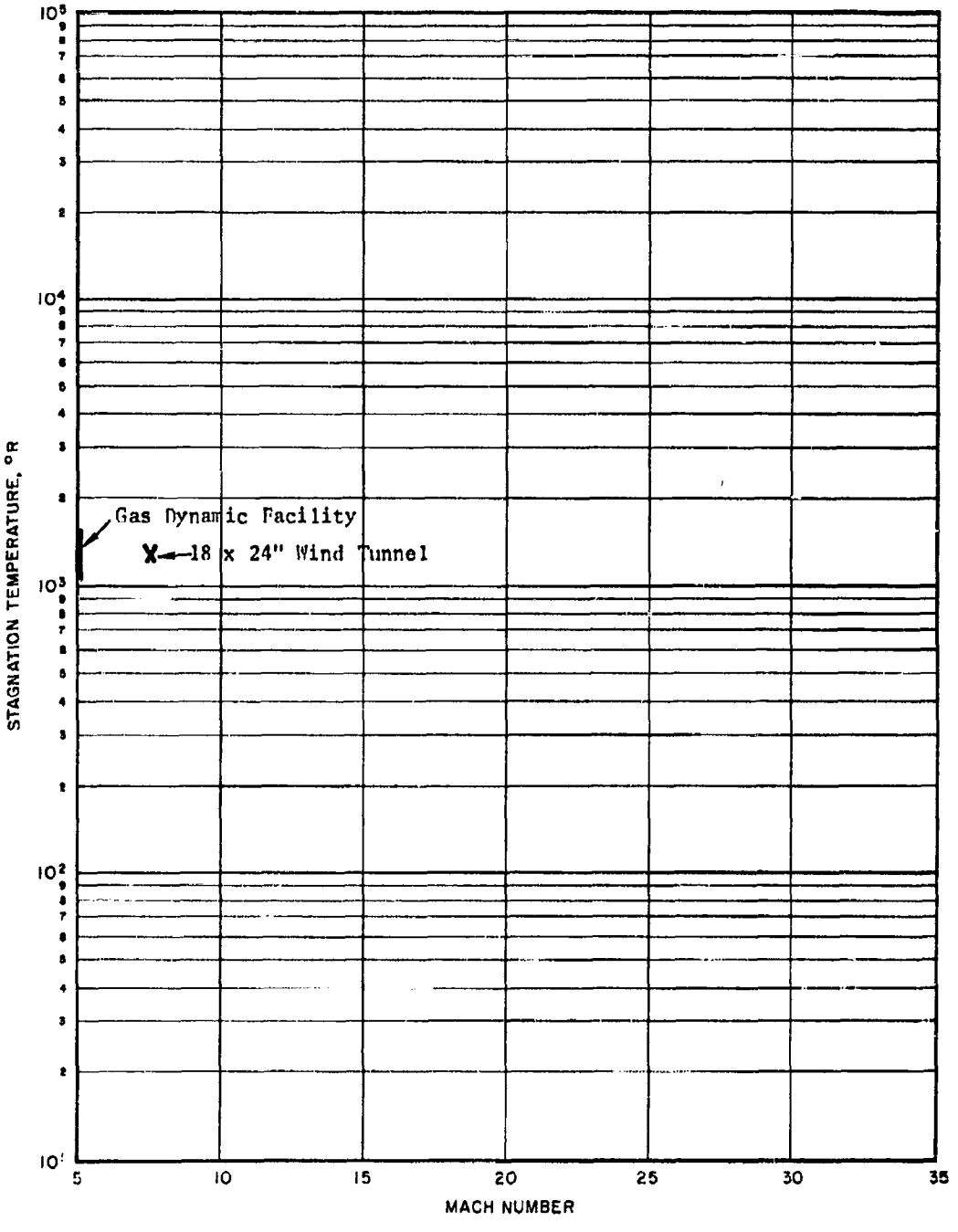
1. Letter, Morton Finston to F. A. Vicente, dated 7 September 1962, with enclosures.

2. Letter, William F. Byrne to N. S. Foy, dated 19 December 1962, with enclosures.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Gas Dynamic Facility
18 x 24" Wind Tunnel
5
10
15
20
25
30
35

MIT AEROPHYSICS LABORATORY




STAGNATION TEMPERATURE, °R
MACH NUMBER
Gas Dynamic Facility
18 x 24" Wind Tunnel
5
10
15
20
25
30
35

Name of Facility

MAC Hypervelocity Impulse Tunnel (HIT)
McDonnell Aircraft Corporation
Box 516
St. Louis 66, Missouri

Person Responsible

Lamar A. Ramos, Jr., Manager, HIT

Type

This facility is an impulse tunnel of the hotshot type.

Nozzle and Test Section

The Hypervelocity Impulse Tunnel uses a 5^{o} half angle conical nozzle. It has a 30-inch diameter or 50-inch diameter test section, and test core diameters ranging from 15 to 45 inches. The tunnel can accommodate an 80 square inch model at all test conditions and models having frontal areas over 300 square inches at some test conditions.

Instrumentation and Test Capabilities

Force, pressure and heat transfer instrumentation is available. Balances are constructed to satisfy specific load ranges and requirements. 6 component balances can be constructed if required. 50-channel high speed FM tape recorder-reproducer system, support equipment, supplementary recording mediums, shadowgraph system, and Fastax cameras are available as required.

Running Time

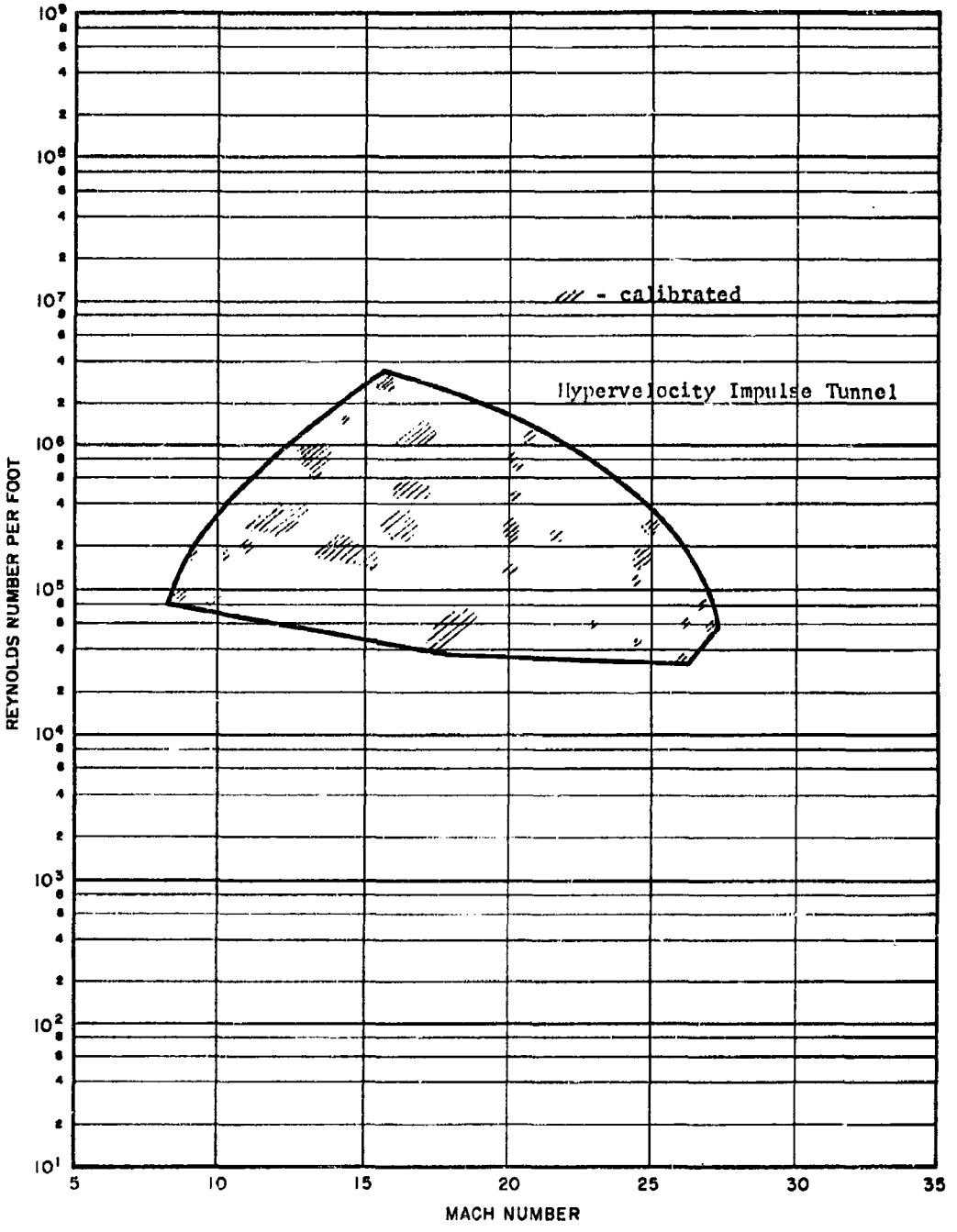
Usable run times in this facility are a minimum of 30 milliseconds and flow is always dumped before 100 milliseconds.

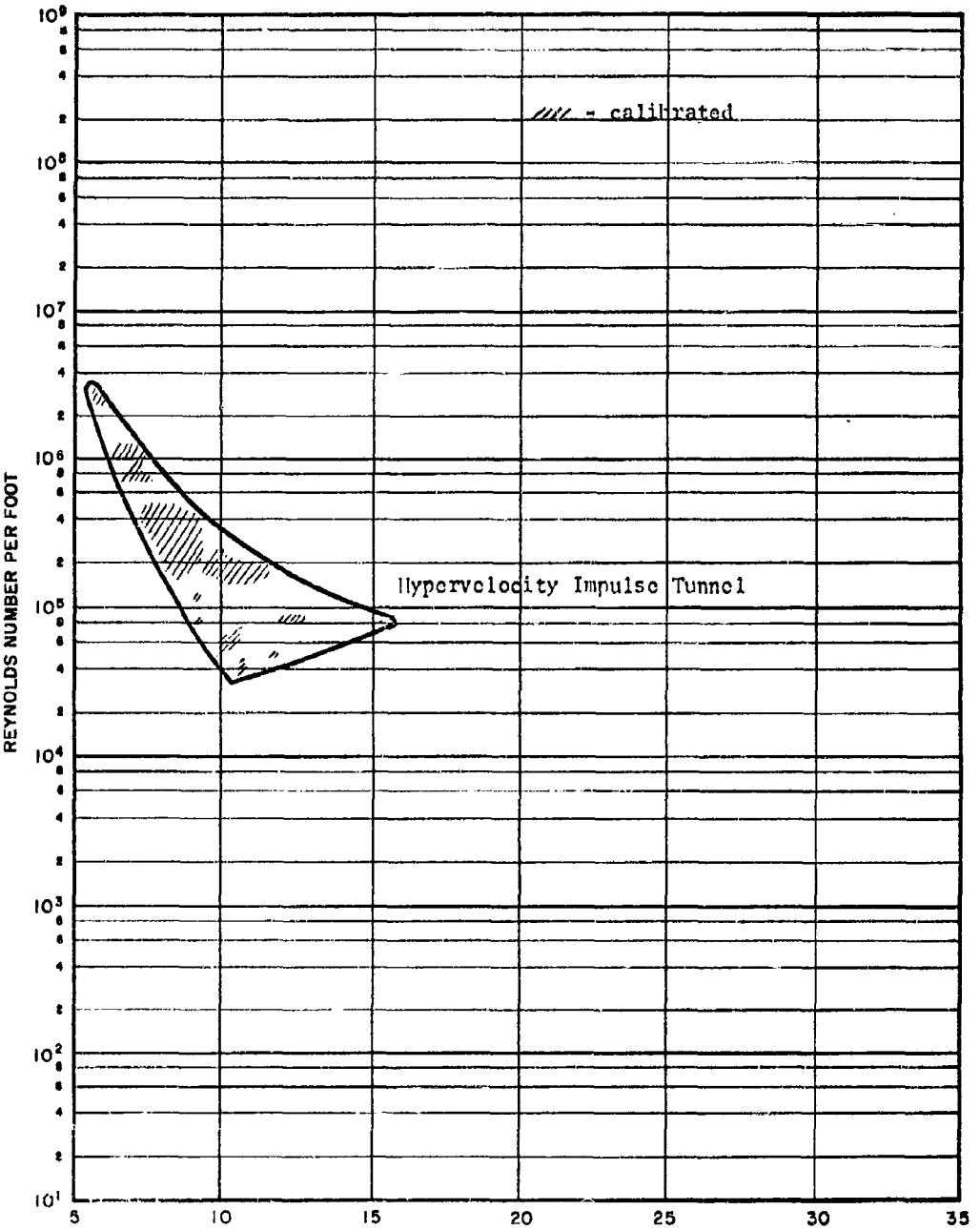
References

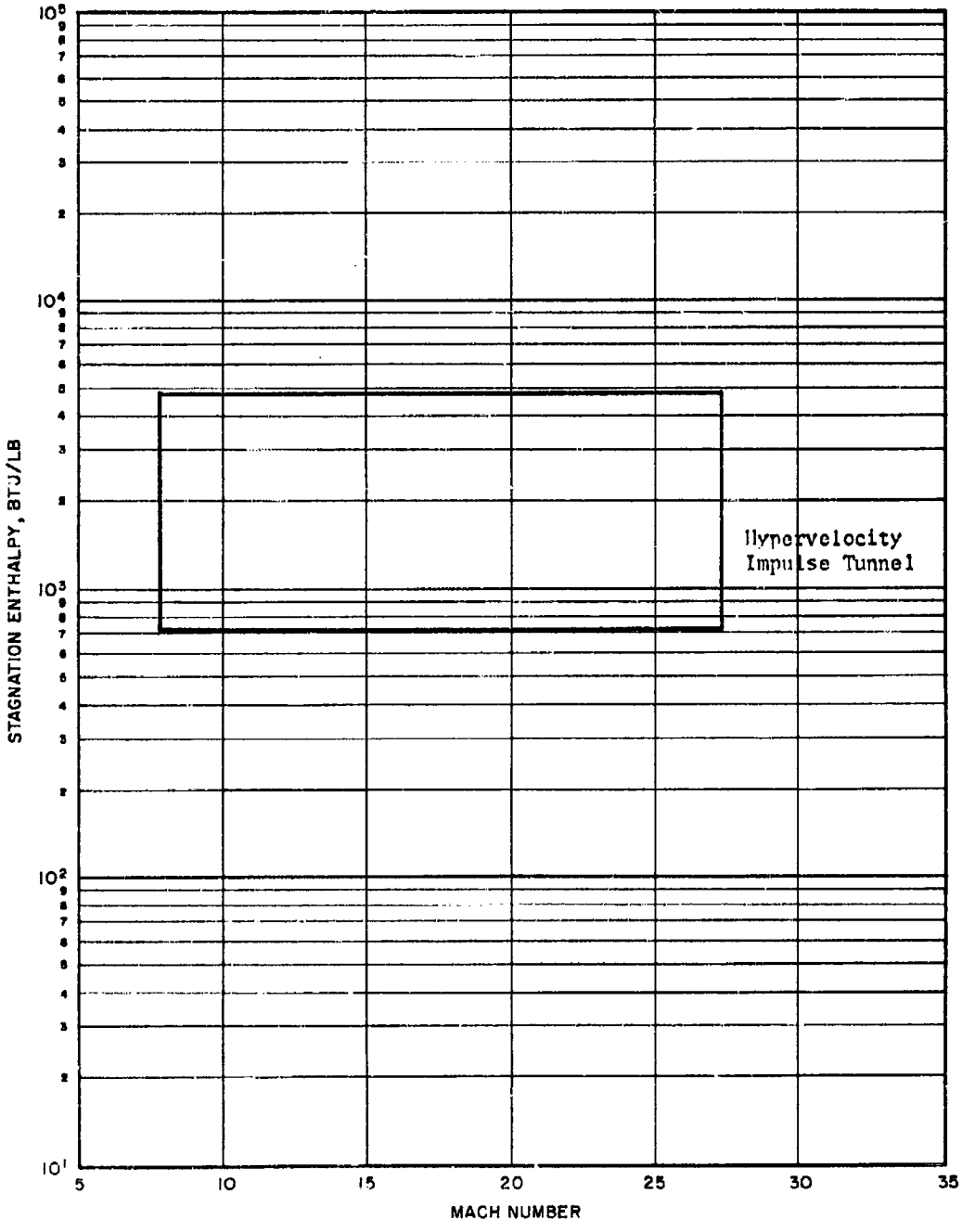
1. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.

2. Letter, R. E. Rohtert to S. T. Chu, 27 July 1962, with enclosures.

3. Letter, L. A. Ramos, Jr. to N. S. Foy, MAC Ref. AC-254-31128, 5 March 1963, with enclosures.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35
- calibrated
Hypervelocity Impulse Tunnel


REYNOLDS NUMBER PER FOOT
VELOCITY, THOUSANDS OF FEET PER SECOND
////- calibrated
Hypervelocity Impulse Tunnel
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
Hypervelocity
Impulse Tunnel
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35

Name of Facility

NASA Ames Research Center
Moffett Field, California

Person Responsible

Smith J. DeFrance, Director
NASA Ames Research Center

Type

The NASA Ames facilities are all intermittent blowdown wind tunnels. The Mass Transfer and Aerodynamics Facility, which is still in the developmental stage, will have two test sections, both 30 inches in diameter. The Mass Transfer section will run at Mach numbers to 10, enthalpy levels to 10,000 BTU/lb and stagnation pressures to 120 psia. The Aerodynamic facility will run at Mach numbers to 18, enthalpy levels to 1500 BTU/lb and stagnation pressures to 1500 psia. The operational facilities at NASA Ames are:

A) The 14 Inch Helium Nozzle facility, which has a test section 14 inches in diameter and 36 inches long. It has Mach number capabilities of 10.7, 17.7 and 21.

B) The 3.5 Foot Hypersonic Wind Tunnel, which has a 3.5 foot diameter test section, 90 inches long, and Mach number capabilities of 5, 7, 10 and 15.

C) The Hypersonic Helium Tunnel, which has a 20 inch diameter test section, with Mach number capabilities of 8, 15, 20, and 26.

Instrumentation and Test Capabilities

All of the Ames facilities are used for research, and are instrumented accordingly. No further information is available regarding specific test capabilities.

Running Times

A) 14 Inch Helium Nozzle Facility - 10 minutes.

B) 3.5 Foot Hypersonic Wind Tunnel - 1 to 4 minutes.

C) Hypersonic Helium Tunnel - 40 seconds at M = 8, 90 seconds at M = 15, 105 seconds at M = 20 and 120 seconds at M = 26.

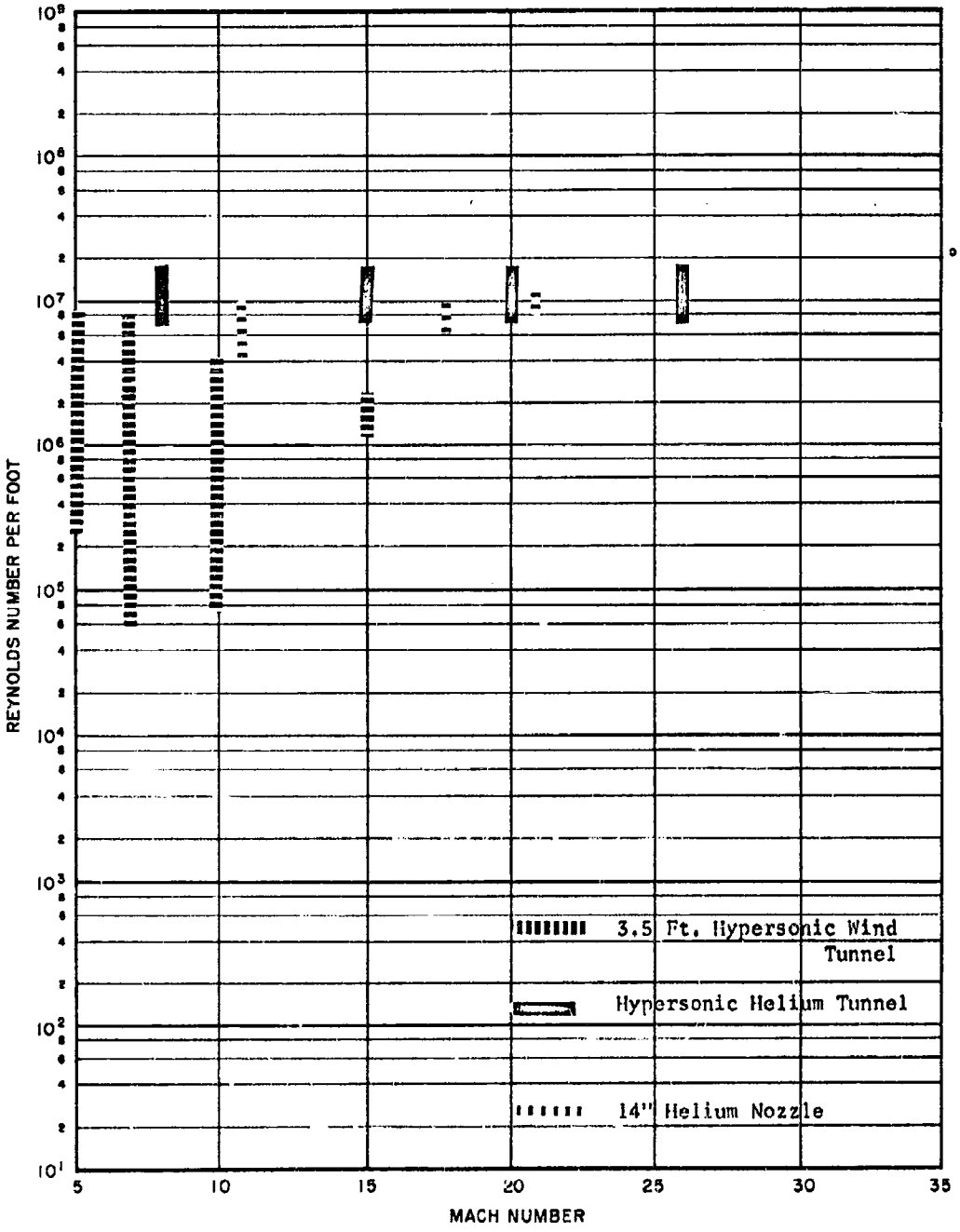
References

1. "National Wind Tunnel Summary", NASA Report, dated July 1961.

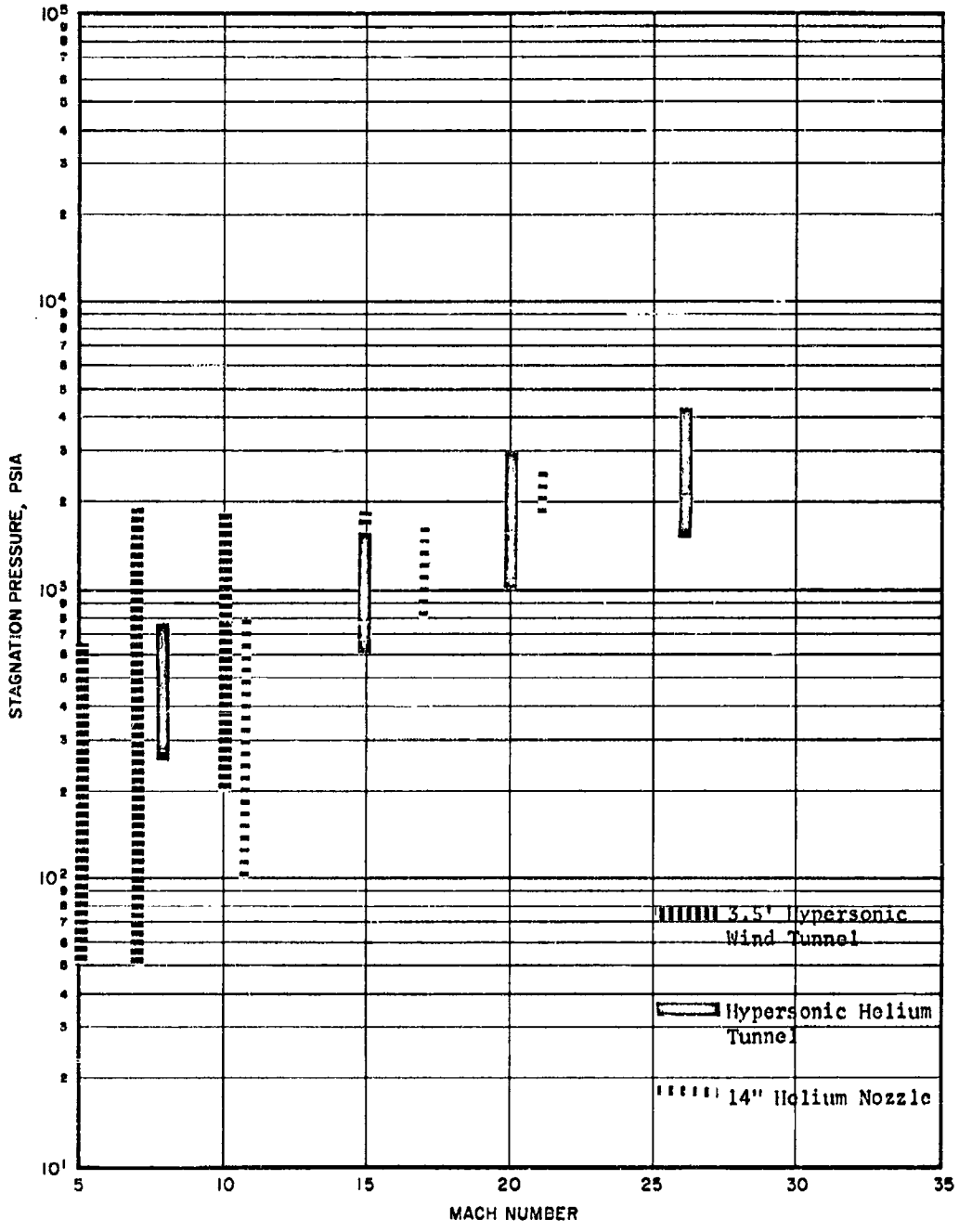
2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, dated April 1960.

3. Letter, S. J. DeFrance to N. S. Foy, dated 7 January 1963.

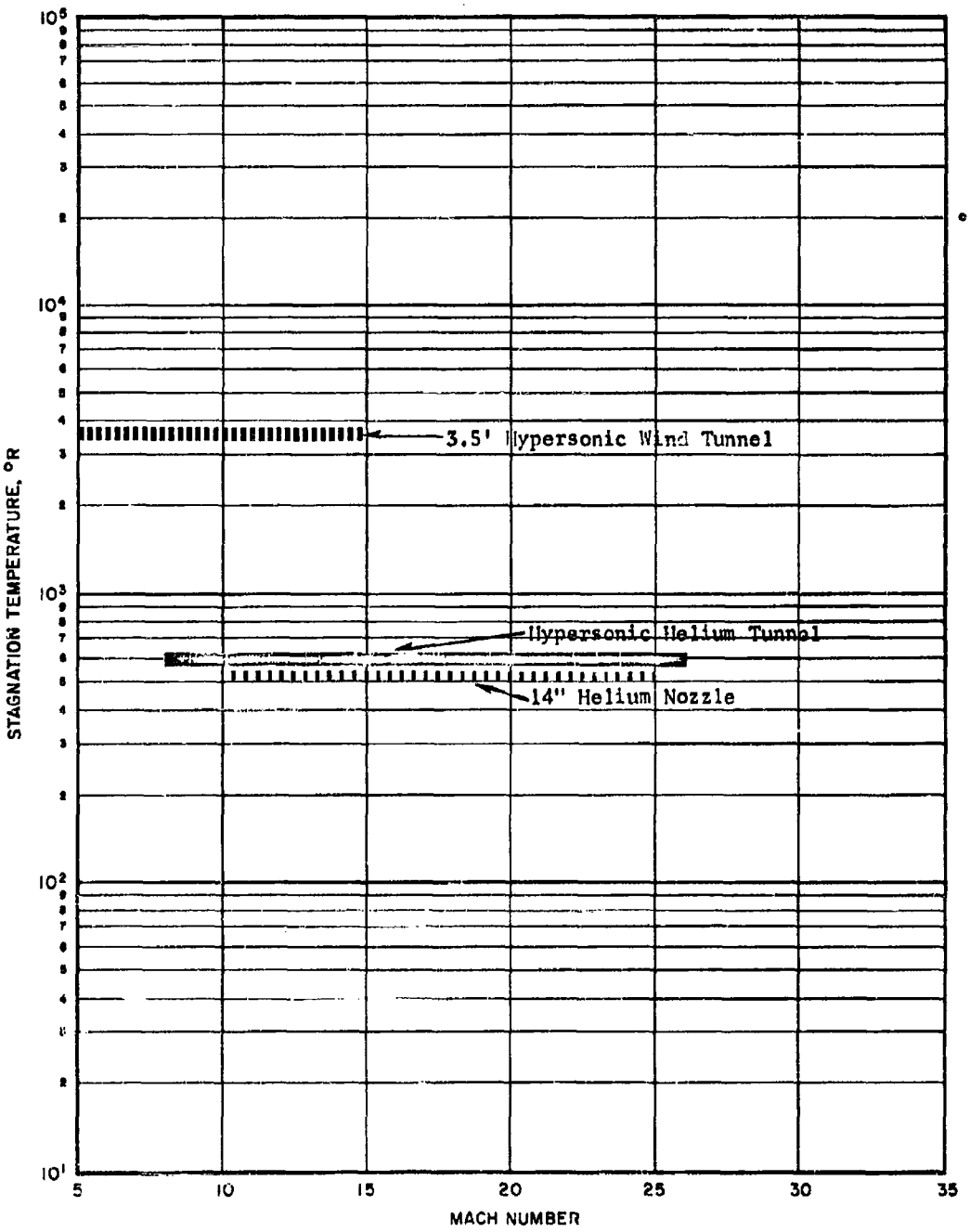
NASA AMES RESEARCH CENTER



NASA AMES RESEARCH CENTER



NASA AMES RESEARCH CENTER



Name of Facility

NASA Langley Research Center
Aero-Physics Division - Small Hypersonic Facilities
Langley Field, Virginia

Person Responsible

NASA Director, NASA Langley Research Center

Type

Following are the smaller hypersonic facilities in the Aero-Physics Division at NASA Langley. They are all of the intermittent blowdown type.

A) 11 Inch Hypersonic Tunnel

B) 20 Inch Mach 6 Tunnel

C) 22 Inch Mach 8.5 Tunnel

D) 22 Inch Helium Tunnel

E) Mach 8 Variable Density Hypersonic Tunnel

F) Mach 6 Low Density Hypersonic Tunnel

Nozzle and Test Section

A) The 11 Inch Hypersonic Tunnel has four interchangeable nozzles, two for air (M = 6.8 and 9.6) and two for helium (M = 10.5 and 18). The 6.8 nozzle is two dimensional, and all the others are conical. Test section size ranges from 10.5 square inches at center of the test section to 11.0 square inches at the end of the nozzle.

B) The 20 Inch Mach 6 Tunnel has a 20 by 20.5 inch test section with fixed nozzle.

C) The 22 Inch Mach 8.5 Tunnel has a circular test section, 22 inches in diameter.

D) The 22 Inch Helium Tunnel has a circular test section, 22 inches in diameter, and a conical nozzle with interchangeable throats which give a Mach number range of approximately 15 to 28. Useable test core is about 14 inches.

E) The Mach 8 Variable Density Hypersonic Tunnel has a circular test section, 18 inches in diameter.

F) The test section for the Mach 6 Low Density Hypersonic Tunnel is 12 inches by 14 inches.

Instrumentation and Test Capabilities

A) The 11 Inch Hypersonic Tunnel is not connected with an automatic data reduction system. No injection mechanism is available for heat transfer tests, but rather the "quick start" technique is used for such tests. This facility is equipped to do pressure and temperature investigations and force testing.

B) No further information is available regarding instrumentation and test capabilities for the 20 Inch Mach 6 Tunnel.

C) No further information is available regarding instrumentation and test capabilities of the 22 Inch Mach 8.5 Tunnel.

D) The 22 Inch Helium Tunnel is presently equipped to obtain 6 component static force and moment data, pressure distribution (up to 40 pressure leads per test) and heat transfer data (up to 72 thermocouples per test). The data can be recorded on either of two types of instruments: 30 channels are available on oscillographs, and up to 99 channels on a Beckman 210 digital data recording system. For visual observation of the flow, a conventional single pass Schlieren system is available.

E) No further information is available regarding instrumentation and test capabilities of the Mach 8 Variable Density Hypersonic Tunnel.

F) No further information is available regarding instrumentation and test capabilities of the Mach 6 Low Density Tunnel.

Running Times

A) 11 Inch Hypersonic Tunnel - M = 6.8 nozzle - 70 to 100 seconds
M = 9.6 nozzle - 100 seconds
M = 10.5 nozzle - 14 seconds
M = 18 nozzle - 10 seconds

B) 20 Inch Mach 6 Tunnel - 3 to 30 minutes

C) 22 Inch Mach 8.5 Tunnel - 3 to 30 minutes

D) 22 Inch Helium Tunnel - 20 to 40 seconds

E) Mach 8 Variable Density Hypersonic Tunnel - 2 to 30 minutes

F) Mach 6 Low Density Tunnel - 2 to 30 minutes

References

1. Letter, Floyd L. Thompson to F. A. Vicente, 13 September 1962.

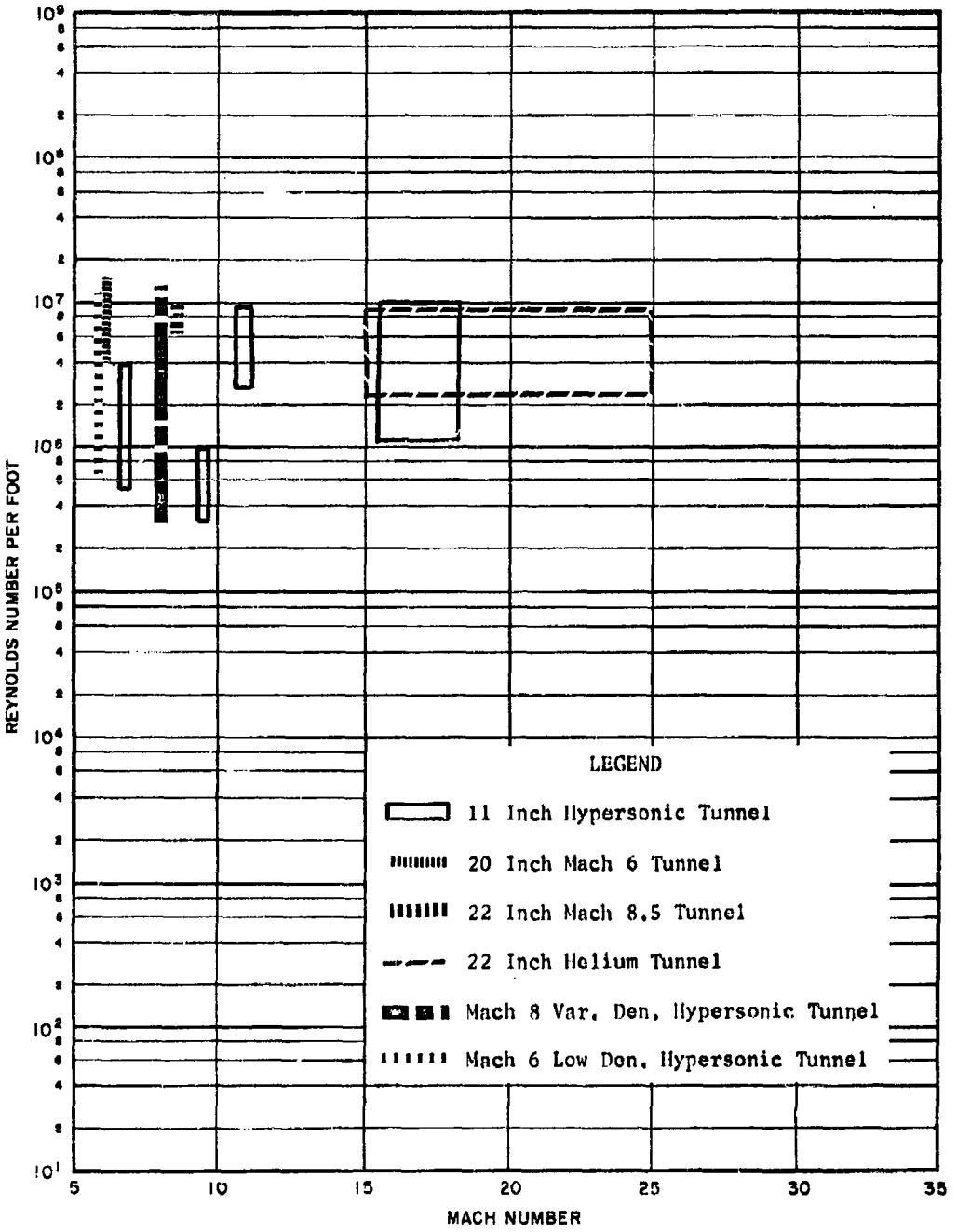
2. "National Wind Tunnel Summary," NASA Report, July 1961.

3. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States," Boeing Report No. D2-5785, April 1960.

4. Letter, Floyd L. Thompson to N. S. Foy, 23 January 1963, with enclosures.

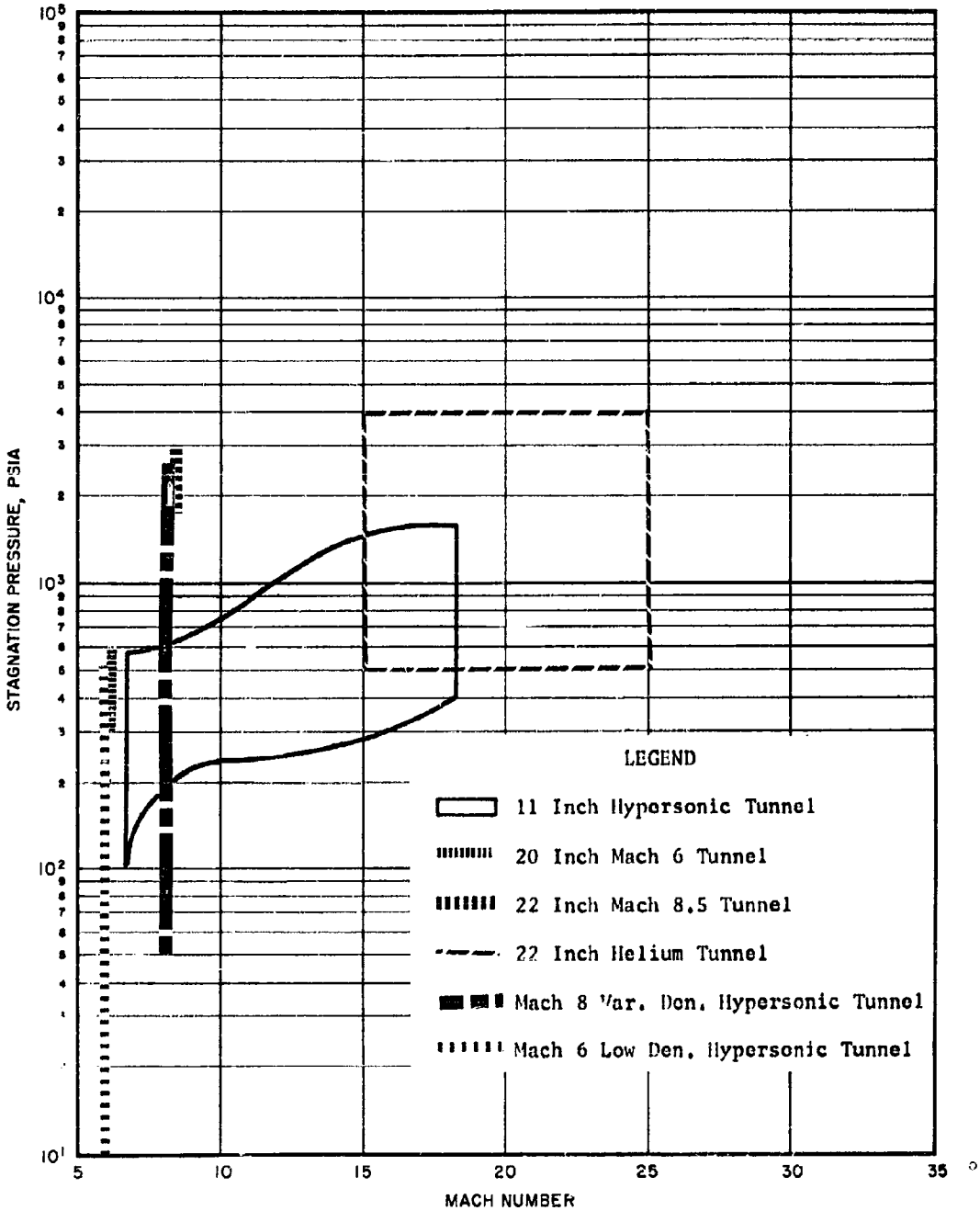
NASA LANGLEY RESEARCH CENTER

Aero-Physics Division - Small Hypersonic Facilities



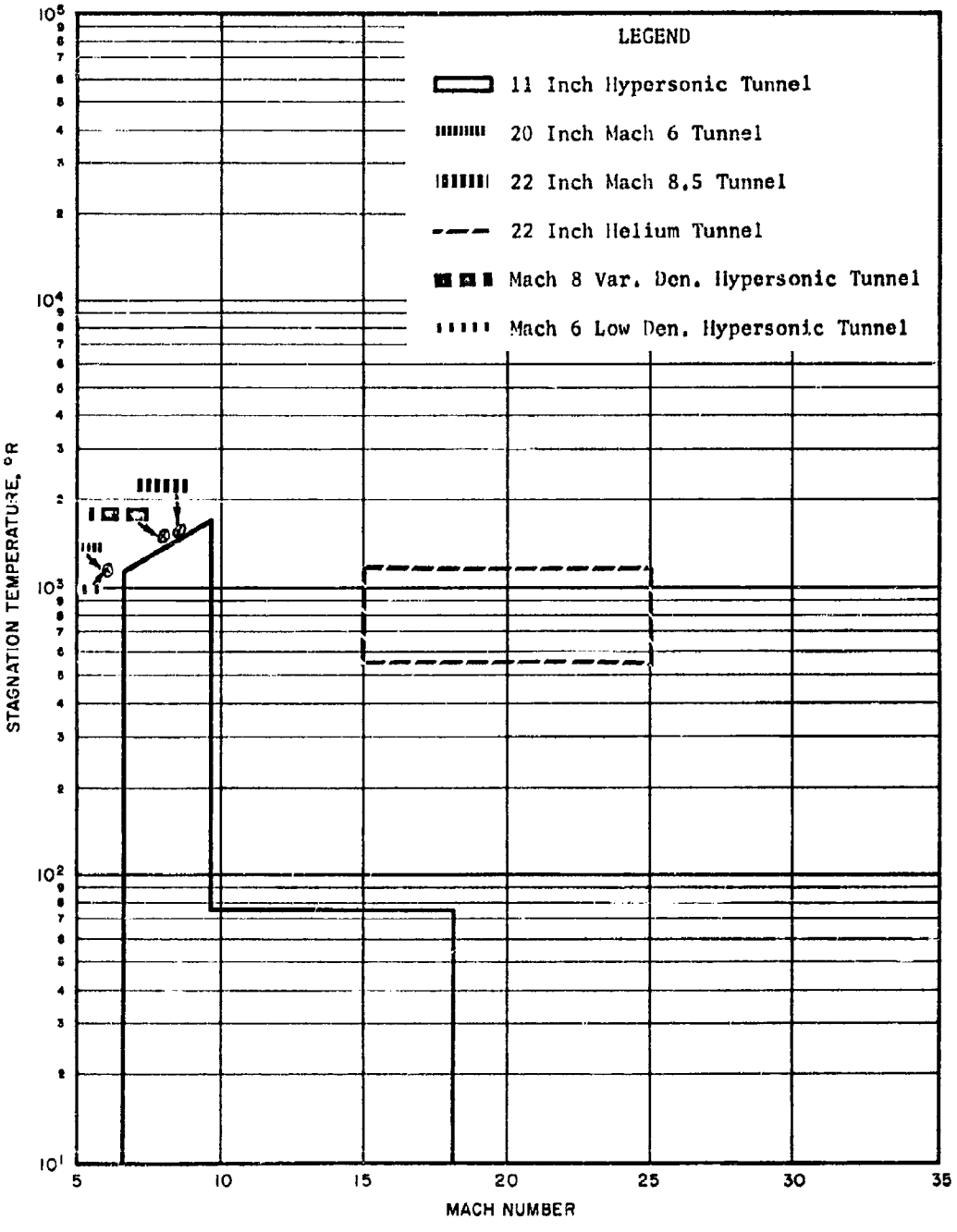
NASA LANGLEY RESEARCH CENTER

Aero-Physics Division - Small Hypersonic Facilities



NASA LANGLEY RESEARCH CENTER

Aero-Physics Division - Small Hypersonic Facilities



Name of Facility

NASA Langley Research Center
Other Divisions - Small Hypersonic Facilities
Langley Field, Virginia

Person Responsible

NASA Director, NASA Langley Research Center

Type

The following small hypersonic facilities are operated by divisions other than the Aero-Physics Division at NASA Langley. The 2 by 2 Foot Low Density Hypersonic Tunnel is of the continuous type. All the other facilities listed are of the intermittent blowdown type.

A) 12 Inch Hypersonic Ceramic Heated Tunnel
(Applied Materials and Physics Division)

B) Hypersonic Aeroelasticity Tunnel (Helium)
(Dynamic Loads Division)

C) 15 Inch Hypersonic Flow Apparatus
(Full-Scale Research Division)

D) 2 by 2 Foot Low Density Hypersonic Tunnel
(Full-Scale Research Division)

Nozzle and Test Section

A) The 12 Inch Hypersonic Ceramic Heated Tunnel has a 12 inch diameter test section, enclosed free jet with downstream diffuser. It has a Mach number capability of 13.

B) The Hypersonic Aeroelasticity Tunnel has an 8 inch diameter test section at M = 7. At M = 15 the test section is 24 inches in diameter.

C) The 15 Inch Hypersonic Flow Apparatus has a 15 inch diameter axisymmetric test section, and a Mach number capability of 10.4.

D) The 2 by 2 Foot Low Density Hypersonic Tunnel has a 24 by 24 by 54 inch test section, with a Mach number range of 3 to 7.

Instrumentation and Test Capabilities

These facilities are used for research, development and evaluation. No information is available on their specific instrumentation and test capabilities at this time.

Running Times

A) 12 Inch Hypersonic Ceramic Heated Tunnel - 30 seconds.

B) Hypersonic Aeroelasticity Tunnel - 20 seconds.

C) 15 Inch Hypersonic Flow Apparatus - 10 minutes.

D) 2 x 2 Foot Low Density Hypersonic Tunnel - continuous.

References

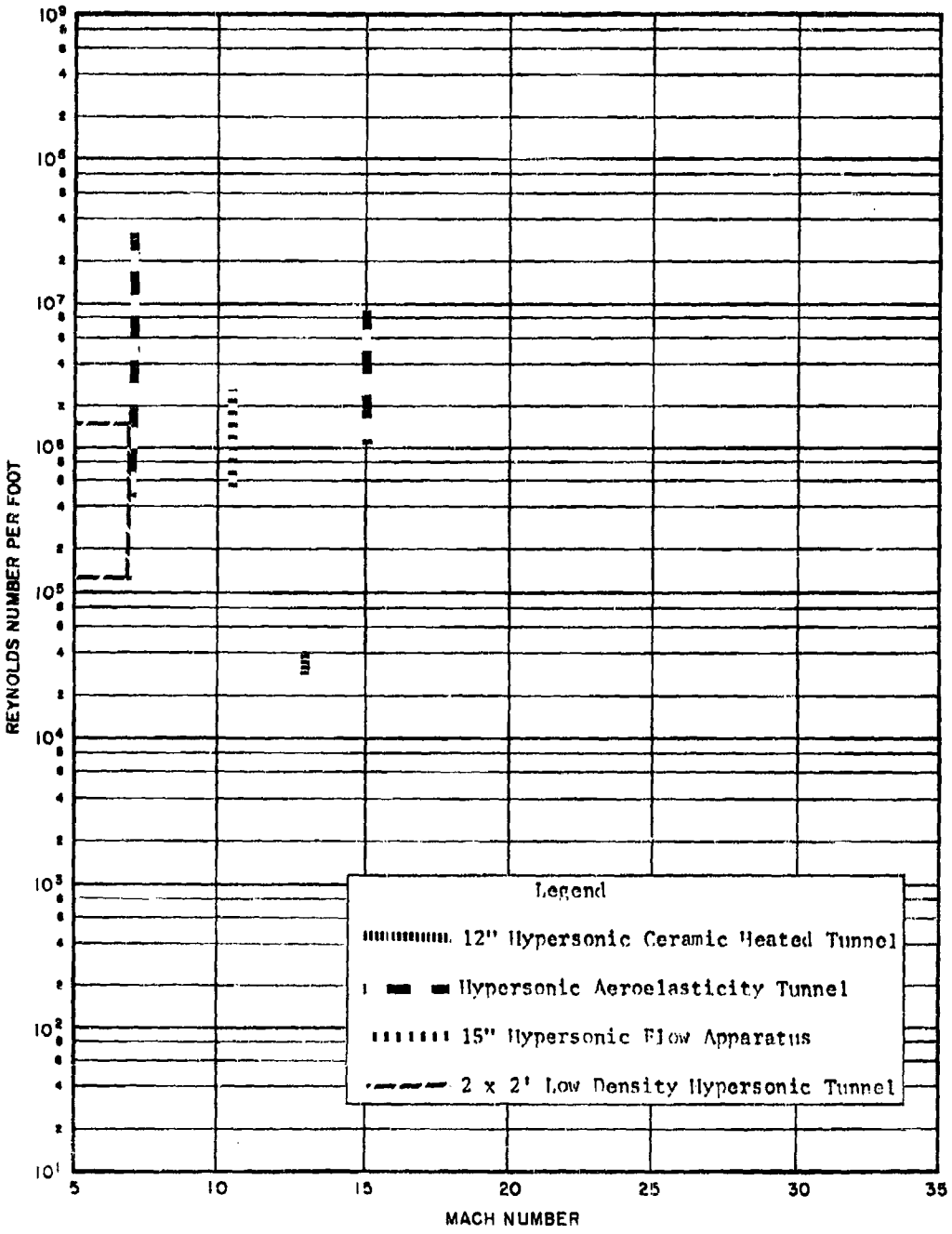
1. "National Wind Tunnel Summary", NASA Report, July 1961.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.

3. Letter, Floyd L. Thompson to N. S. Foy, dated 23 January 1963, with enclosures.

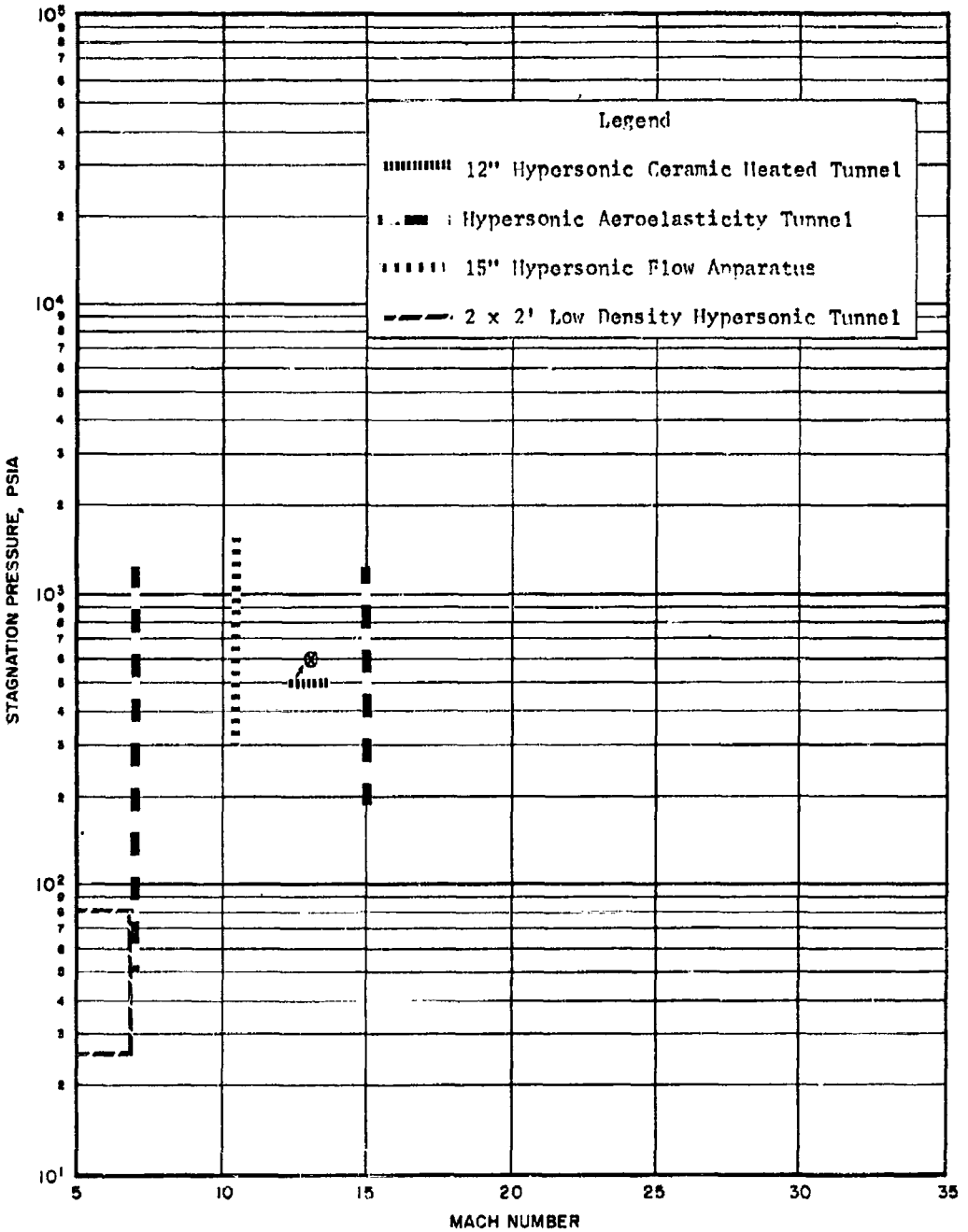
NASA LANGLEY RESEARCH CENTER

Other Divisions - Small Hypersonic Facilities



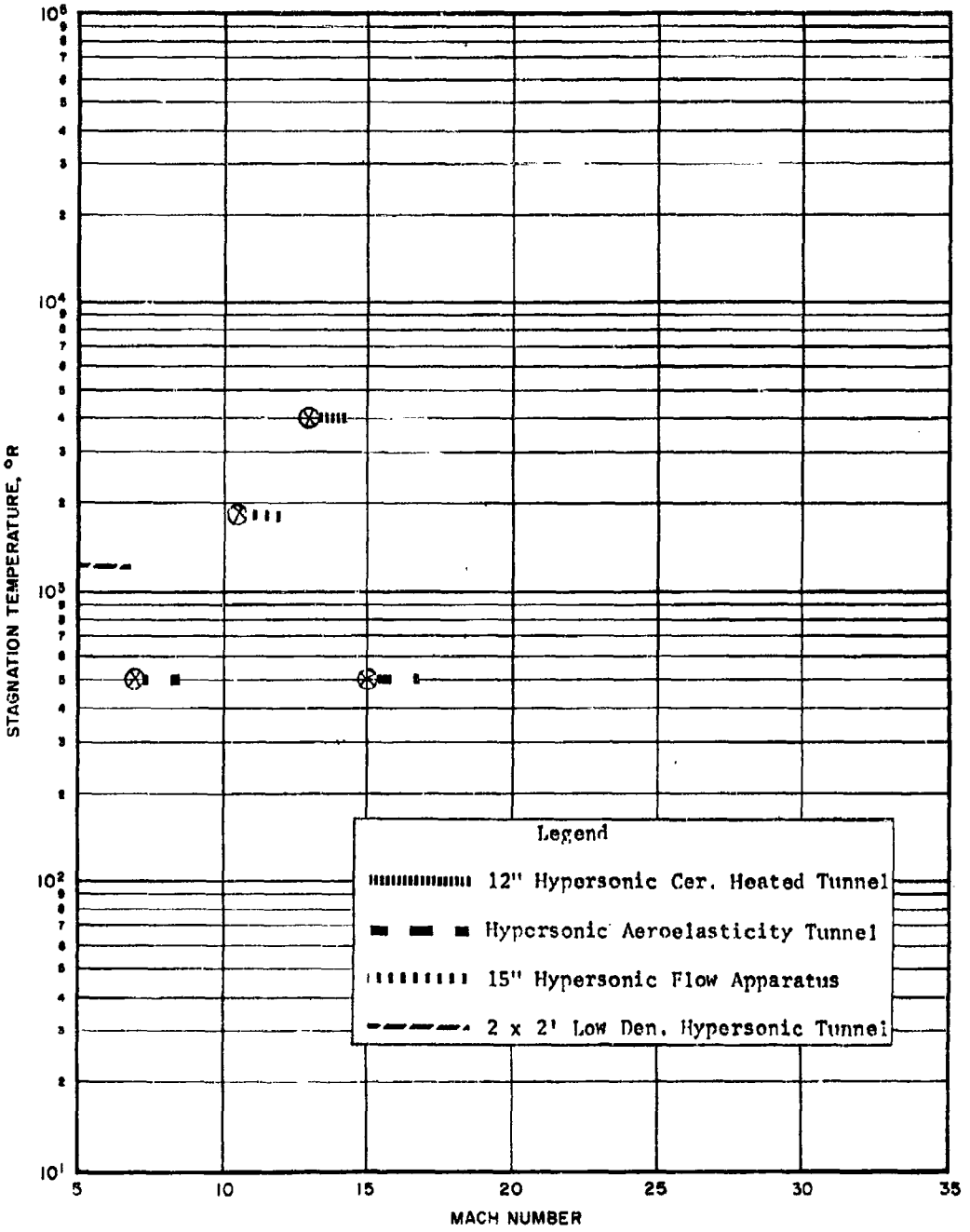
NASA LANGLEY RESEARCH CENTER

Other Divisions - Small Hypersonic Facilities



NASA LANGLEY RESEARCH CENTER

Other Divisions - Small Hypersonic Facilities



Name of Facility

NASA Langley Research Center
Large Hypersonic Facilities
Langley Field, Virginia

Person Responsible

NASA Director, NASA Langley Research Center

Type

Following are the larger hypersonic facilities at NASA Langley. With the exception of the Continuous Flow Hypersonic Tunnel, they are all of the intermittent blowdown type.

A) Continuous Flow Hypersonic Tunnel
(Aero-Physics Division)

B) Hyperthermal Leg, Hypersonic Aerothermal-Dynamics Facility
(Aero-Physics Division)

C) Hypersonic Dynamics Leg (helium)
Hypersonic Aerothermal-Dynamics Facility
(Dynamic Loads Division)

D) 8 Foot High Temperature Structures Tunnel
(Structures Research Division)

Nozzle and Test Section

A) The Continuous Flow Hypersonic Tunnel has a 31 by 31 inch test section and Mach number capabilities of 10 and 12.

B) The Hyperthermal Leg, currently under construction, will have interchangeable 2 foot and 4 foot diameter cylindrical test sections and a Mach number range of approximately 10 to 20. Interchangeable throat sections can be used.

C) The Hypersonic Dynamics Leg has a 3 foot diameter test section at Mach 10 and a 5 foot diameter test section at Mach 20.

D) The 8 Foot High Temperature Structures Tunnel has a test section which is 8 feet in diameter and 14 feet long. It has a Mach number range of approximately 6 to 7.5.

Instrumentation and Test Capabilities

These facilities are used for research and development testing. In the Hyperthermal Leg, automatic data reduction (pressures, thermocouples and forces) will be available. Apparatus for rapid model injection is also under construction.

Running Times

A) Continuous Flow Hypersonic Tunnel - continuous.

B) Hyperthermal Leg - 1 to 5 minutes.

C) Hypersonic Dynamics Leg - 10 seconds.

D) 8 Foot High Temperature Structures Tunnel - up to 4 minutes.

References

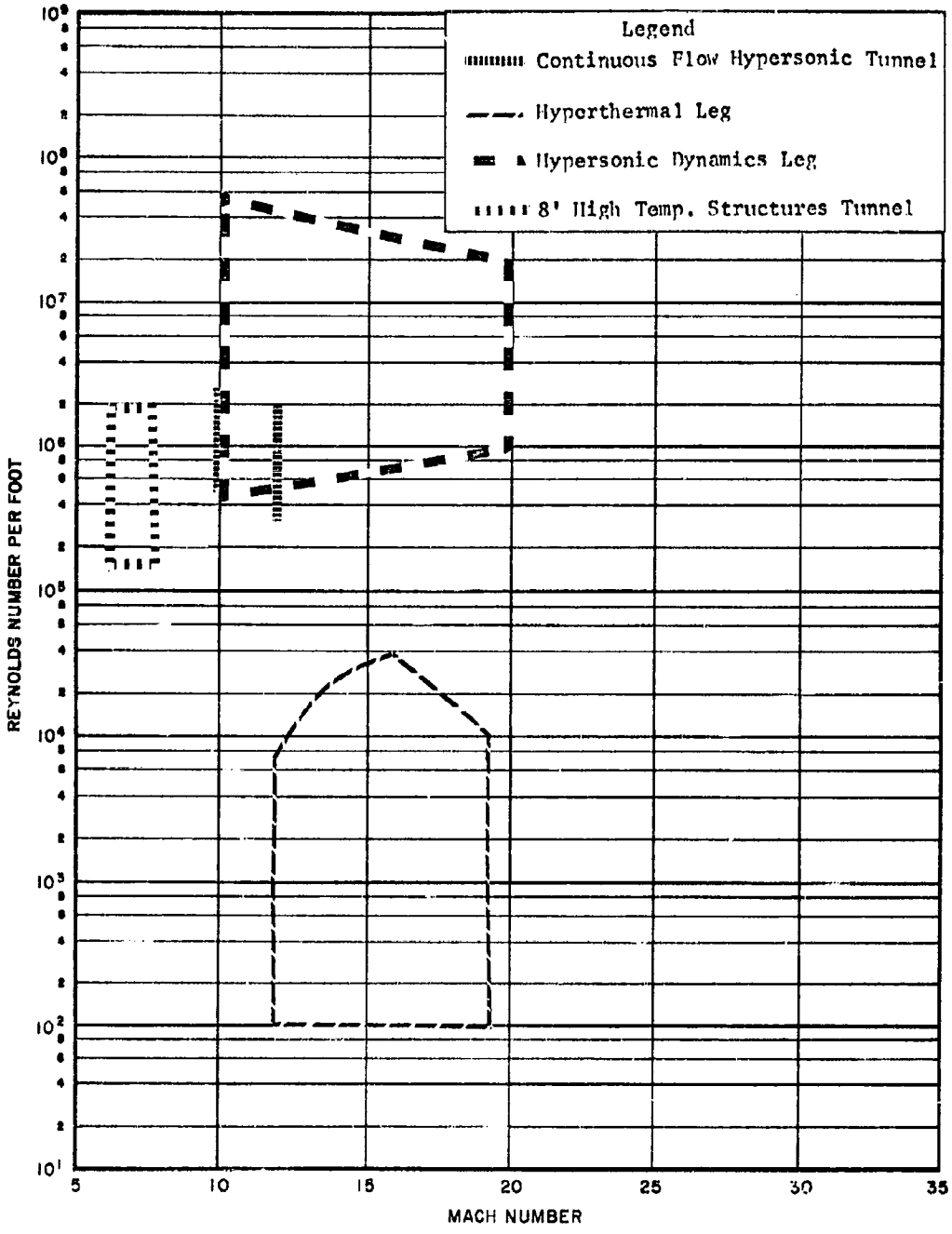
1. "National Wind Tunnel Summary", NASA Report, July 1961.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.

3. Letter, Floyd L. Thompson to N. S. Foy, 23 January 1963, with enclosures.

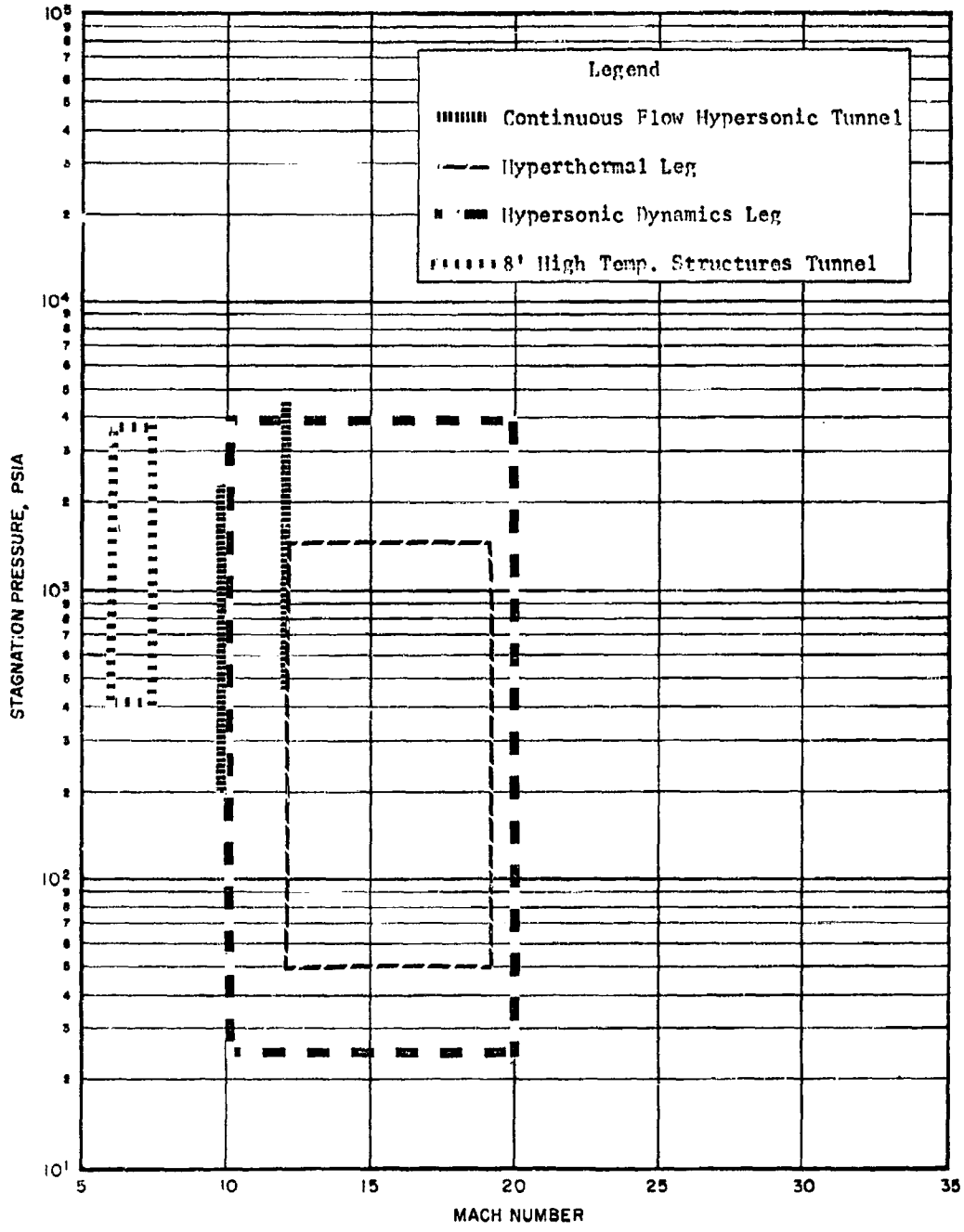
NASA LANGLEY RESEARCH CENTER

Large Hypersonic Facilities



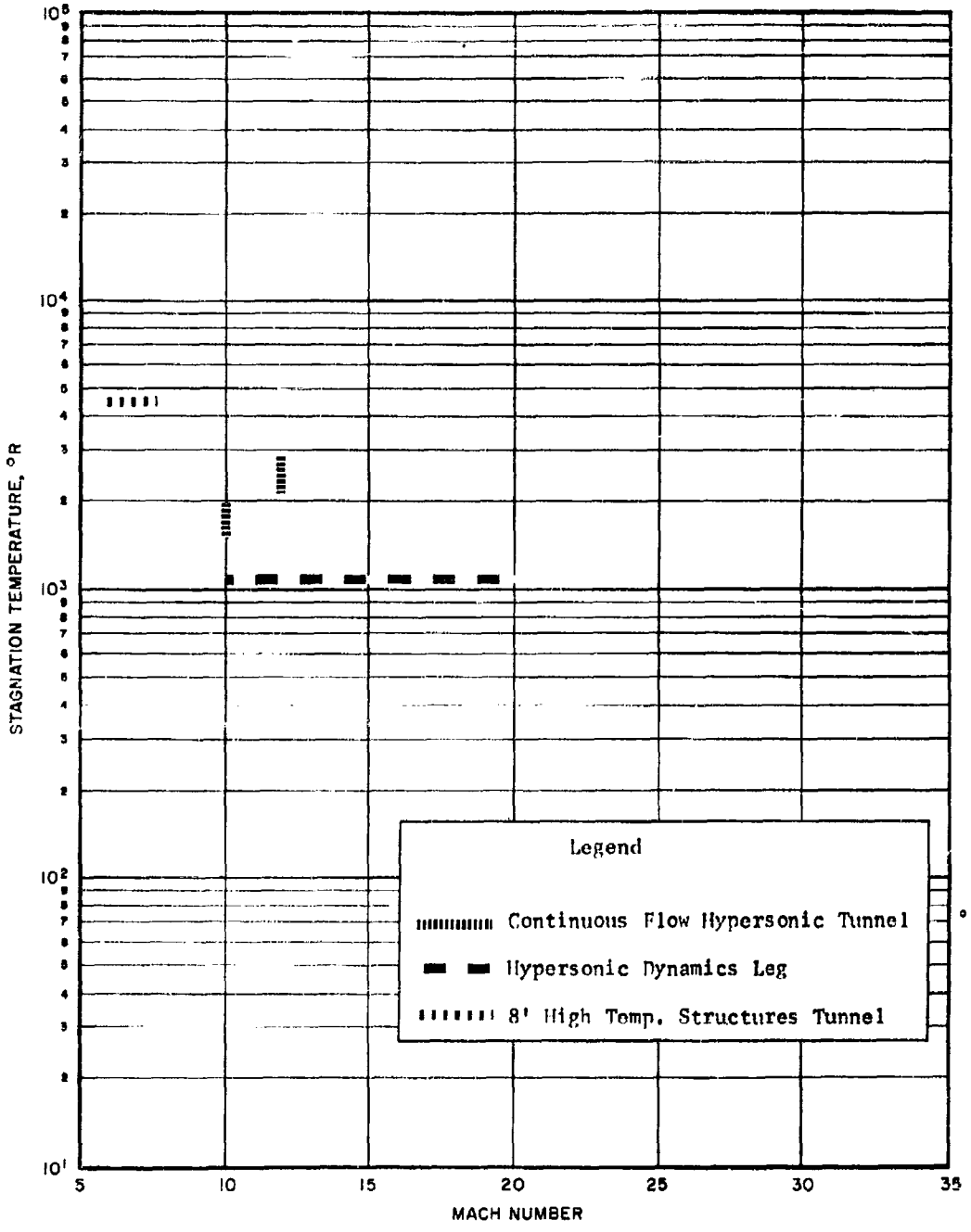
NASA LANGLEY RESEARCH CENTER

Large Hypersonic Facilities



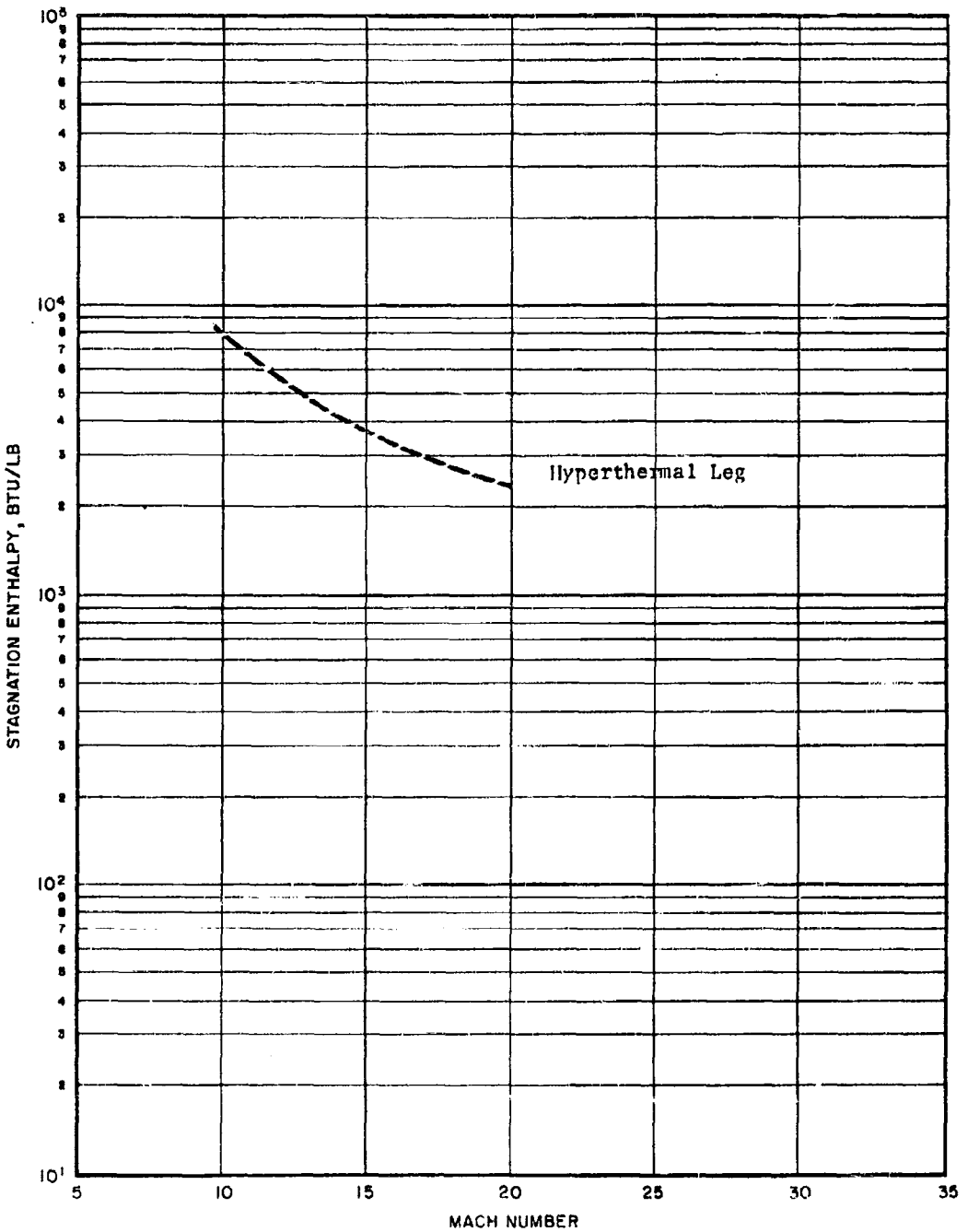
NASA LANGLEY RESEARCH CENTER

Large Hypersonic Facilities



NASA LANGLEY RESEARCH CENTER

Large Hypersonic Facilities



Name of Facility

Lewis Mach 7.0 Hypersonic Wind Tunnel
NASA Lewis Research Center
Cleveland 35, Ohio

Person Responsible

Director, NASA-Lewis Research Center

Type

Continuous

Nozzle and Test Section

The Lewis Hypersonic Wind Tunnel utilizes a conical nozzle, 9^{o} included angle. The test section was calibrated on the centerline over an axial distance of two feet. The test section diameter increased from 22.40" to 24.78" in that distance. Tunnel operates at a dew point of $-50^{o}F$.

Instrumentation and Test Capabilities

Manometer boards and pressure gages are utilized. Schlieren system is also available. This facility has not been in operation since November 1960.

Running Time

Continuous

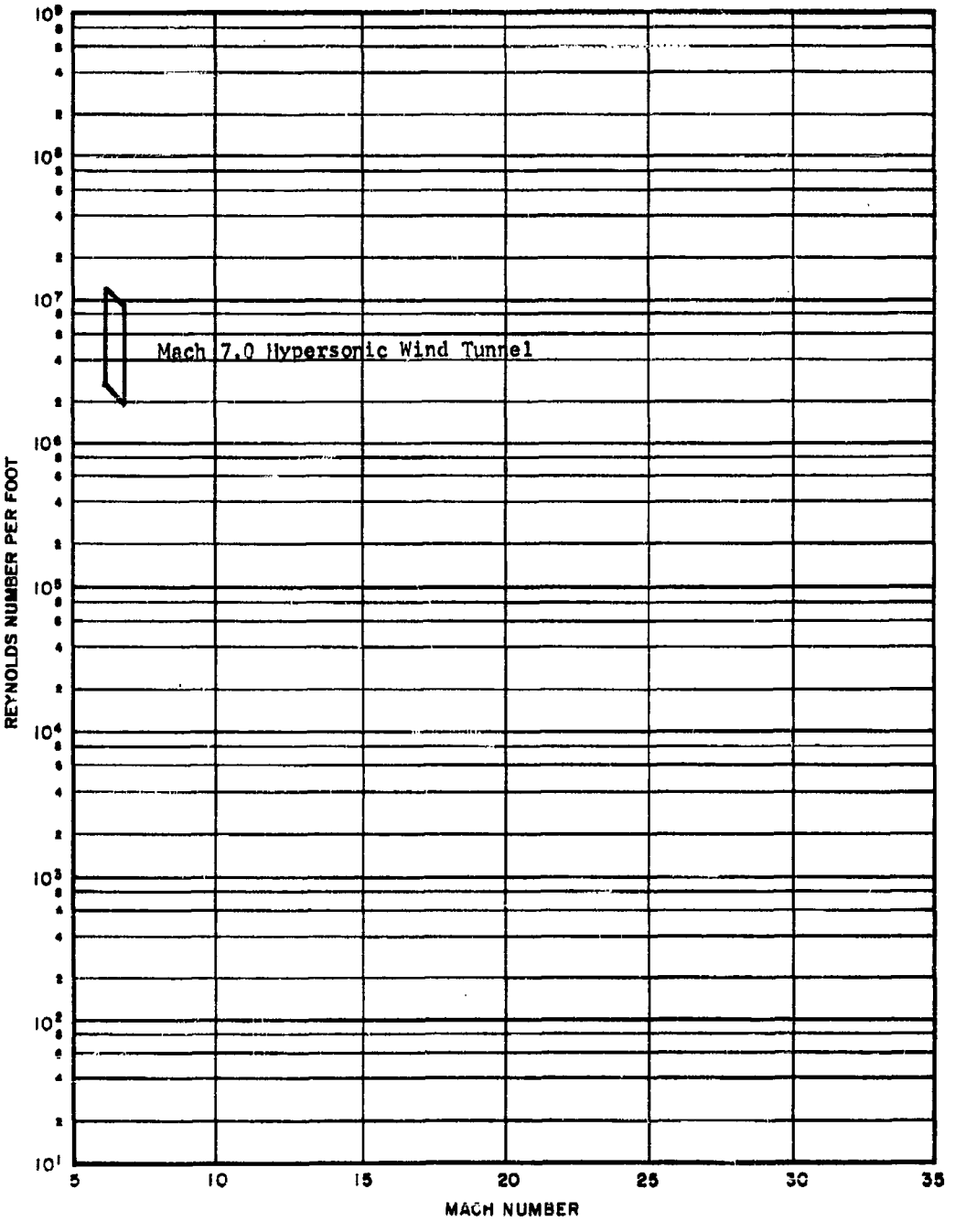
References

1. "National Wind Tunnel Summary", NASA Report, July 1961.

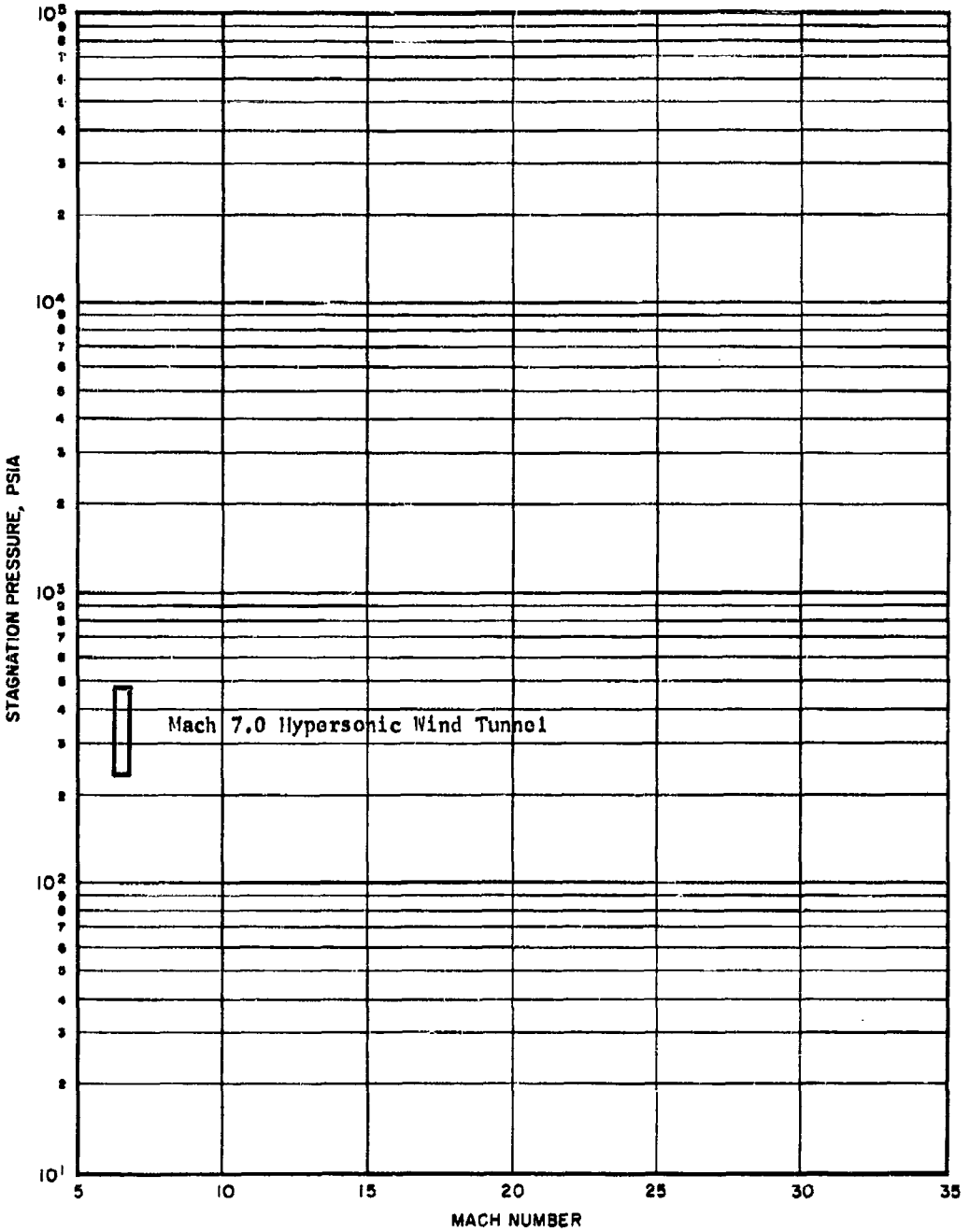
2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.

3. Letter, Leonard E. Stitt to N. S. Foy, dated 7 January 1963.

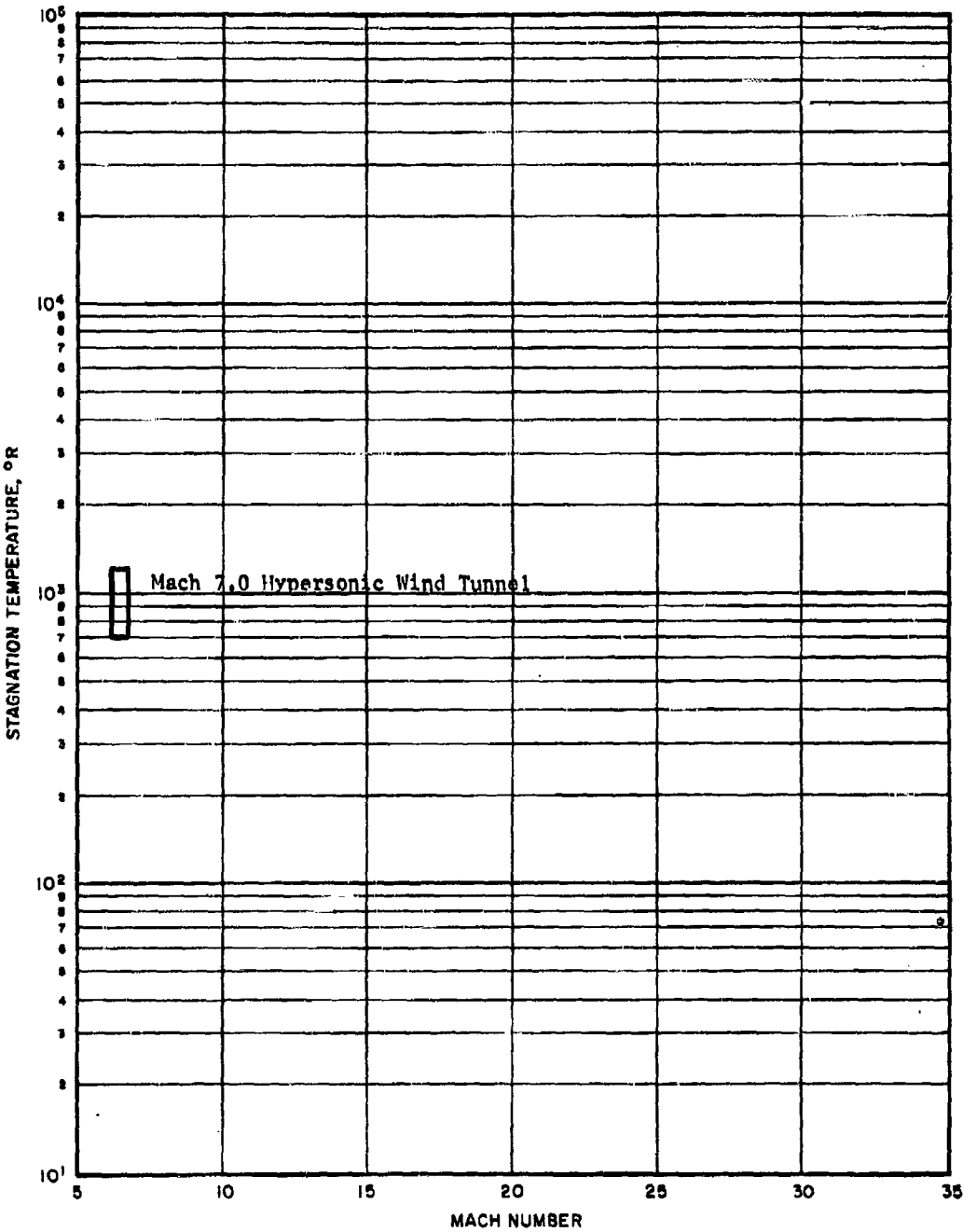
NASA LEWIS RESEARCH CENTER



NASA LEWIS RESEARCH CENTER



NASA LEWIS RESEARCH CENTER



Name of Facility

North American Aviation, Inc.
Los Angeles Division
International Airport
Los Angeles 45, California

Person Responsible

Mr. R. R. Janssen, Director Research Laboratory

Type

A) The 12 Inch Diameter Shock Tunnel has a Mach number range of 7 to 22.

B) The 12 Inch Diameter Hotshot has a Mach number range of 11 to 22.

C) The 17 Inch Diameter Facility, M = 5, 7 and 9, is of the blowdown wind tunnel type. M = 5 and 7 are currently available, and M = 9 will be available about October 1963.

Nozzle and Test Section

A) The 12 inch diameter Shock Tunnel has a usable test core diameter of 6 inches.

B) The 12 inch diameter Hotshot has a usable test core diameter of 6 inches.

C) The 17 inch diameter facility has a usable test core of 17 inches.

Instrumentation and Test Capabilities

A) The 12 inch diameter shock tunnel is operational, and force, pressure and heat transfer tests have been conducted.

B) The 12 inch diameter Hotshot is operational, and heat transfer and ballistic model tests have been conducted. Types of testing suggested include aerodynamic force and pressure, heat transfer, wake survey and flow visualization.

C) The 17 inch facility may be utilized for aerodynamic force and pressure, heat transfer, flow visualization and dynamic flutter testing.

Running Times

A) 12 Inch Diameter Shock Tunnel - 14 milliseconds.

B) 12 Inch Diameter Hotshot - 20 milliseconds.

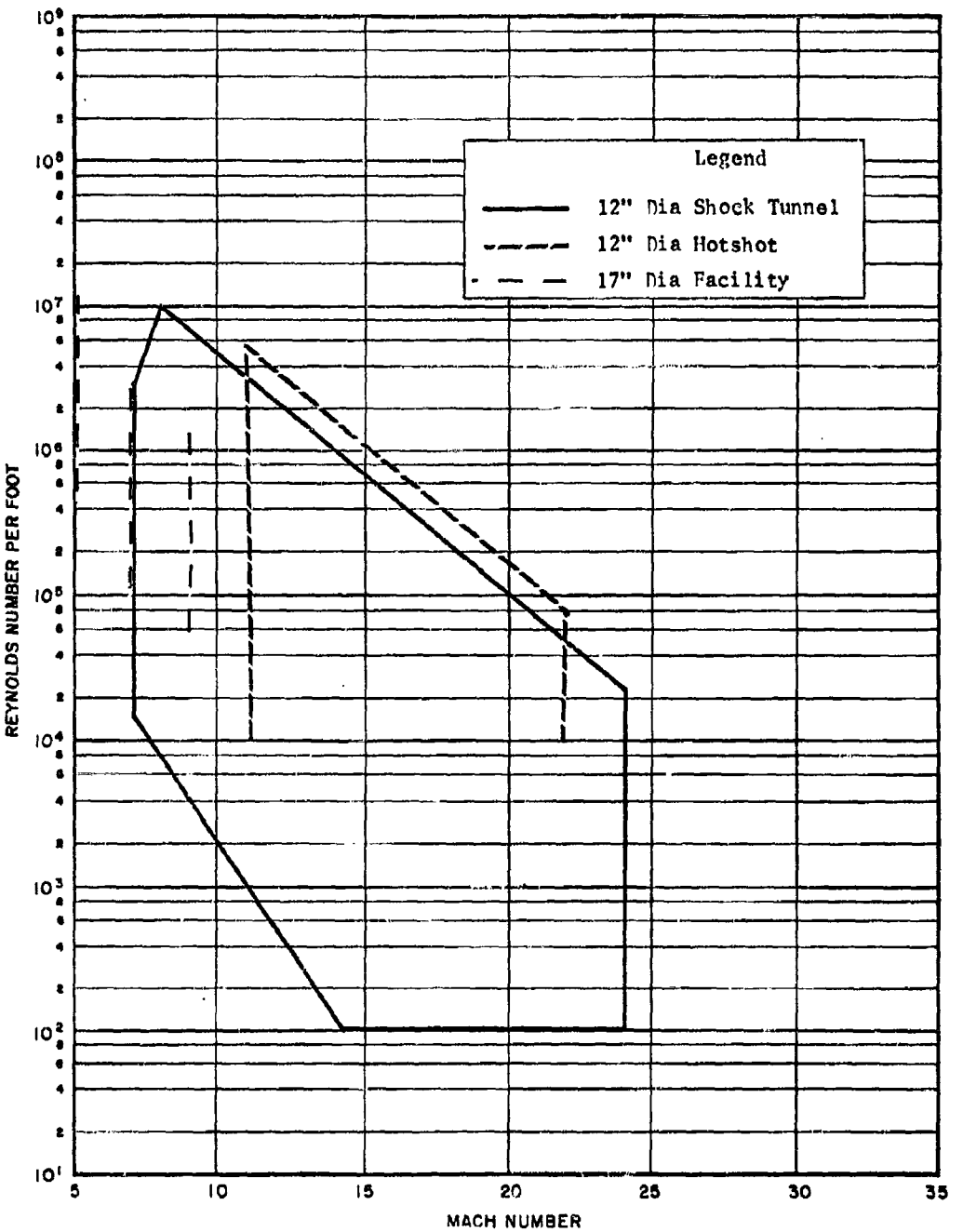
C) 17 Inch Diameter Facility - 40 to 50 seconds for M = 5 and 7. Running times will be from 60 to 90 seconds for M = 9.

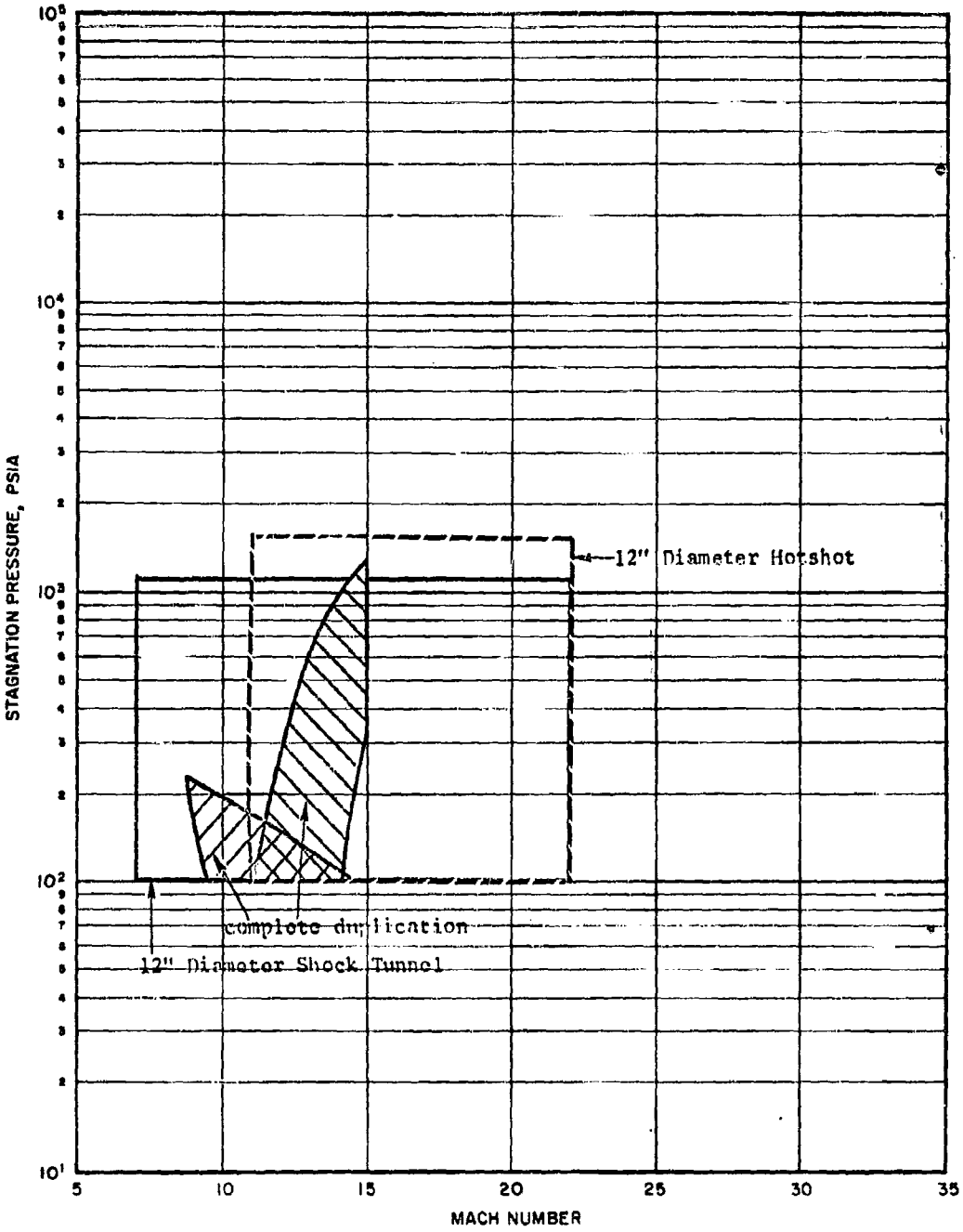
References

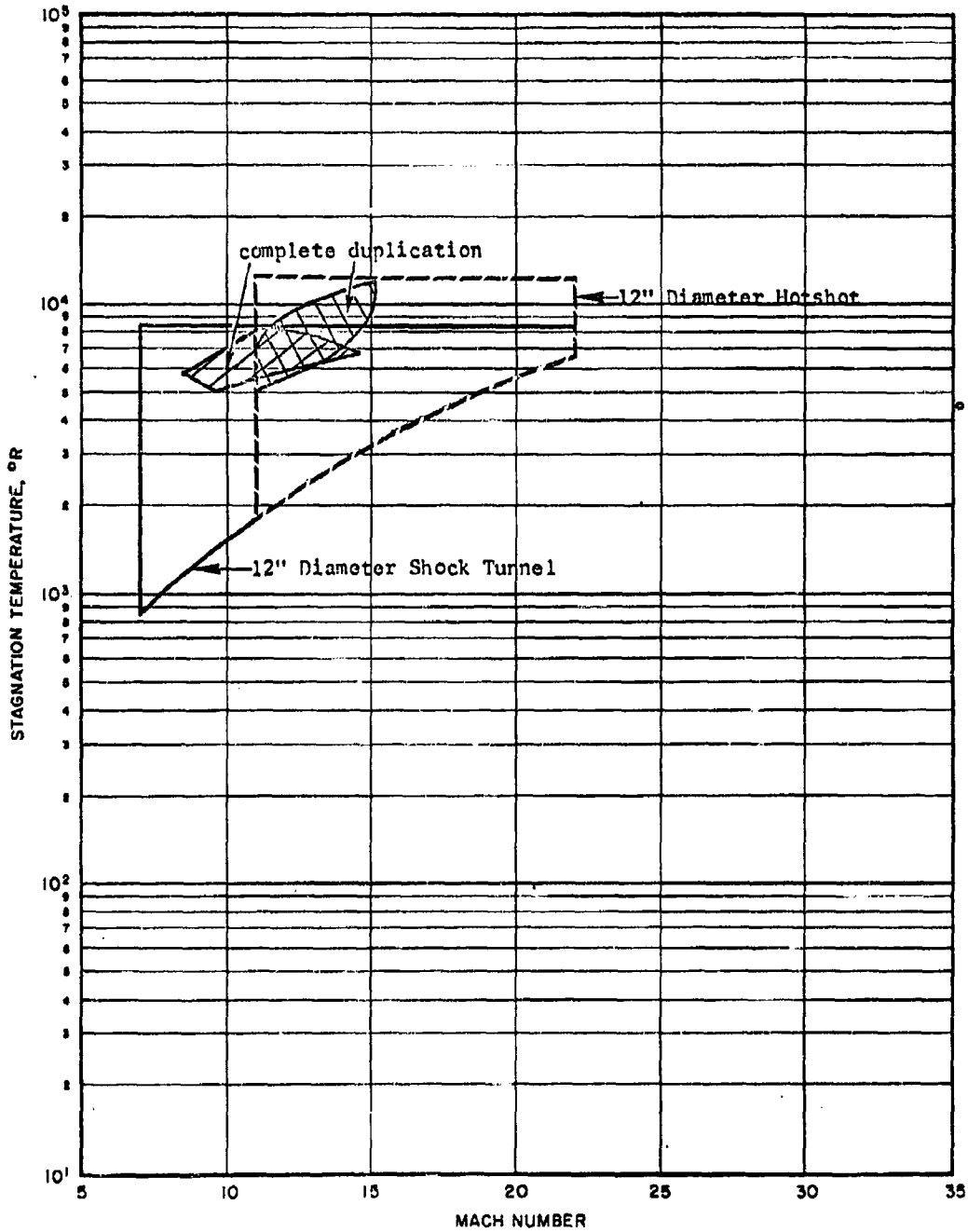
1. "Capabilities and Status of NAA Advanced Facilities", Letter from R. R. Janssen to R. G. Sheffer, NAA No. 62LA11268-280, dated 31 August 1962.

2. "Revised Capabilities and Status of NAA Advanced Facilities", Letter from R. R. Janssen to N. S. Foy, NAA No. 63LA5022-280, dated 4 February 1963.

3. "Operating Characteristics of NAA Advanced Facilities", NAA No. PQ-63-8.


Legend
12" Dia Shock Tunnel
12" Dia Hotshot
17" Dia Facility
REYNOLDS NUMBER PER FOOT
MACH NUMBER
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
12" Diameter Hotshot
complete duplication
12" Diameter Shock Tunnel


complete duplication
12" Diameter Hotshot
12" Diameter Shock Tunnel
STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

Electrodynamics Facility
North American Aviation, Inc.
Space and Information Systems Division
12214 Lakewood Boulevard
Downey, California

Person Responsible

Dr. E. P. French

Type

The Electrodynamics Facility is an arc driven hotshot with an energy storage system of 300,000 joules at 6,000 volts.

Nozzle and Test Section

The test section is 12 inches in diameter. However, models are restricted to 7.5 square inches of frontal area. Nozzle throats are available from 0.05 to 0.15 inches in diameter.

Instrumentation and Test Capabilities

Pressure and heat transfer tests may be run at this facility, with output recording on oscilloscope and oscillograph. High speed camera equipment (up to 26,000 frames per second) is also available to record tests.

Running Time

The Electrodynamics Facility has a useful run time from 20 to 50 milliseconds.

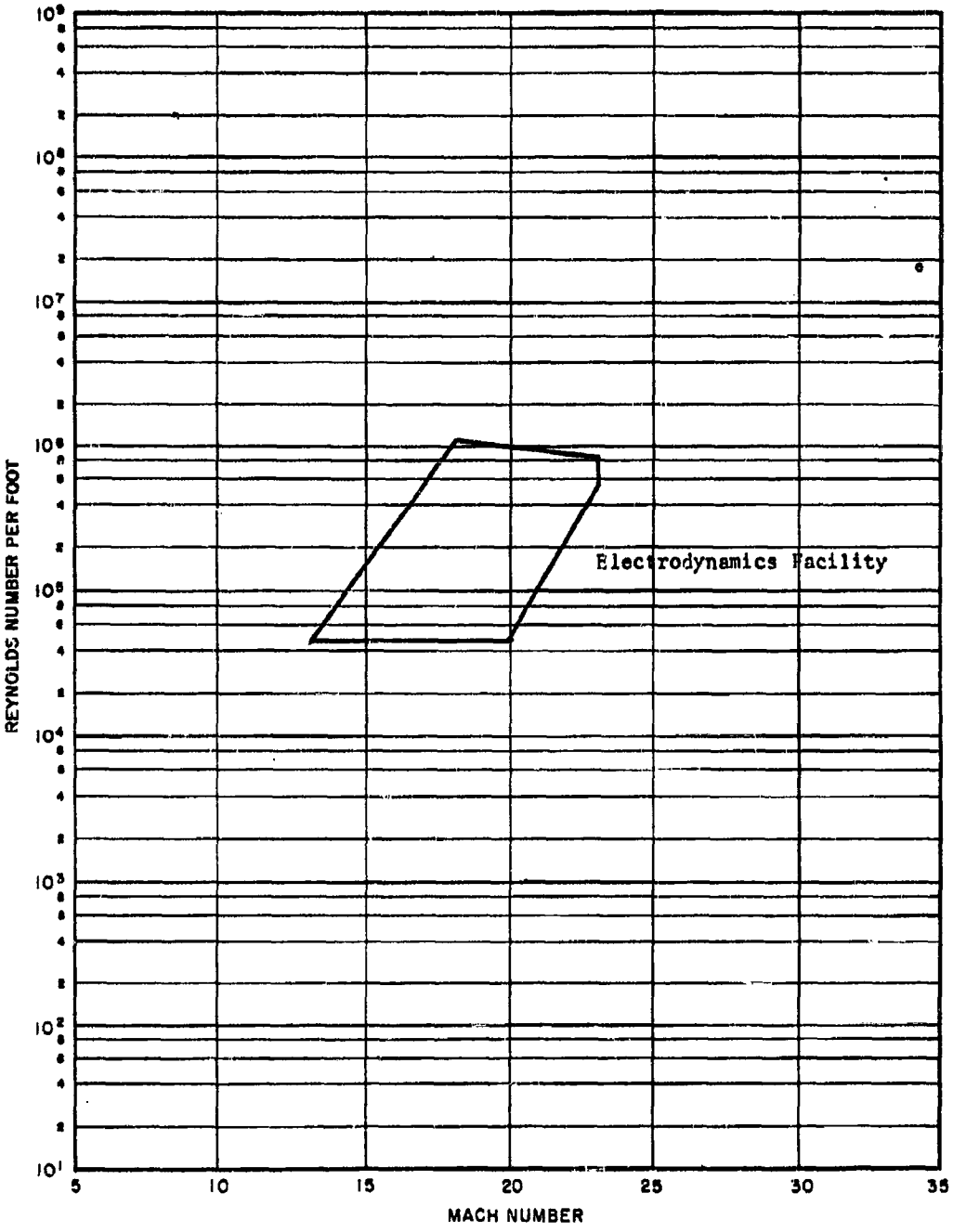
Remarks

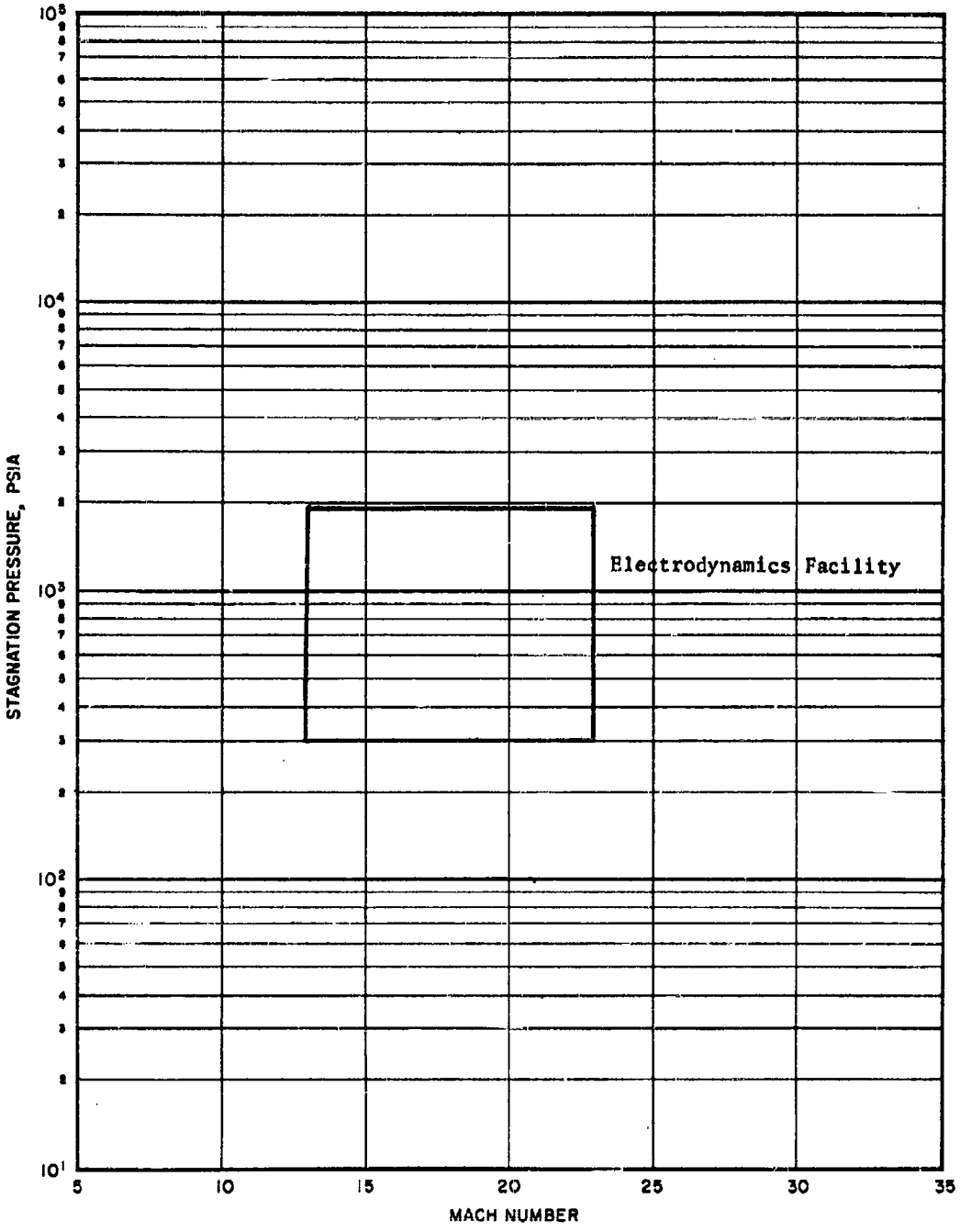
The degree of contamination has not yet been determined. It is believed by the operating staff to be quite low at arc chamber temperatures of less than 4000°K. Air and nitrogen are used routinely as test gases. Helium and argon have been used occasionally.

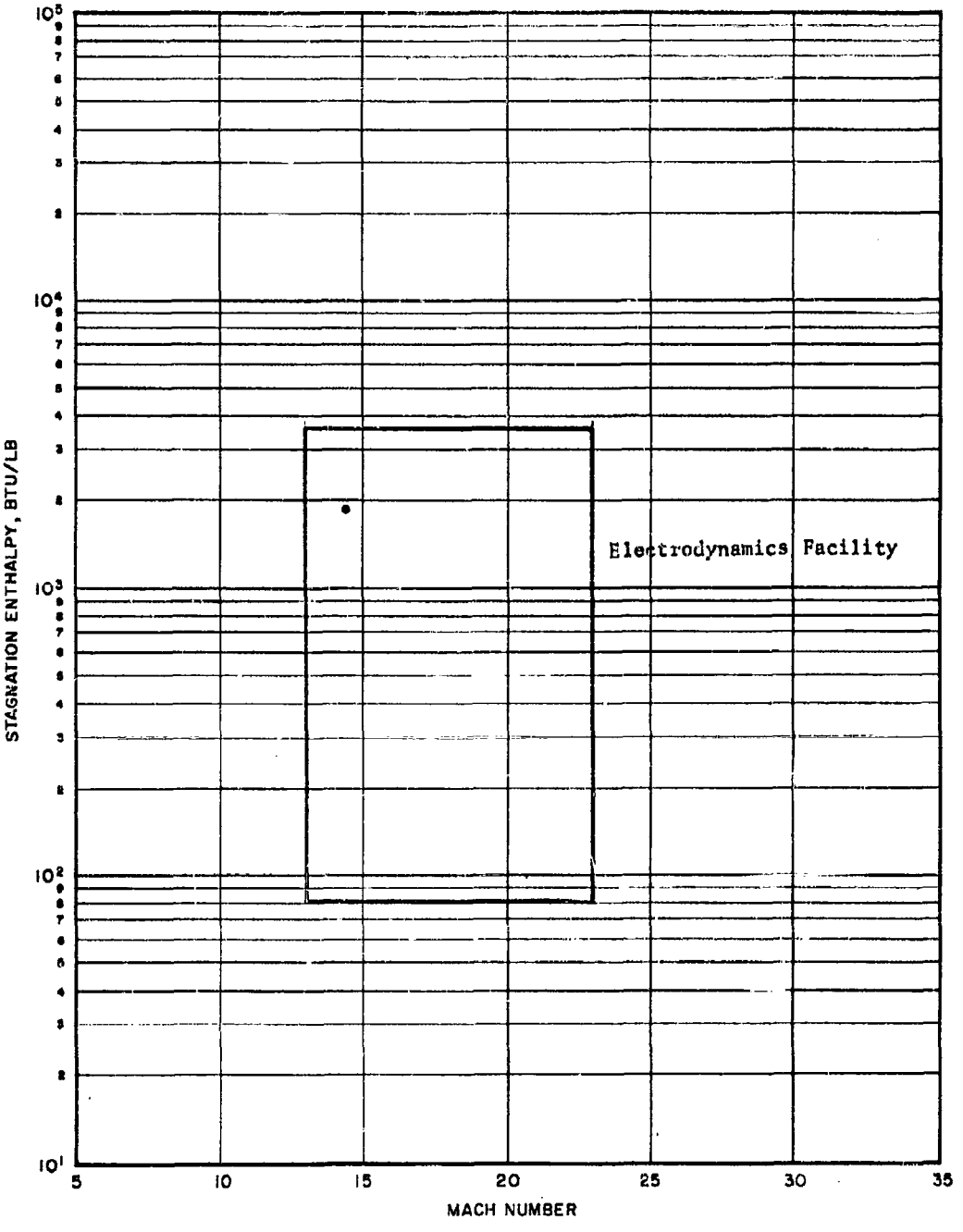
References

1. Letter, E. R. Van Driest to S. T. Chu, dated 12 July 1962.

2. Letter, E. P. French to N. S. Foy, dated January 1962, with enclosures.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Electrodynamics Facility


STAGNATION PRESSURE, PSIA
MACH NUMBER
Electrodynamics Facility
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35


STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
Electrodynamics Facility

Name of Facility

Hypersonic Facility
Northrop Corporation
Norair Division
Hawthorne, California

Person Responsible

Mr. Paul Jensen, Chief, Research Laboratories

Type

The Norair Hypersonic Facility is a 30 inch wind tunnel of the blowdown type, using a pebble bed heater.

Nozzle and Test Section

The nozzles used are of the interchangeable fixed block type. At present, nozzles are available for Mach numbers of 6.0, 10.0 and 14.0. The test section is 30 inches in diameter.

Instrumentation and Test Capabilities

Shakedown and calibration effort was begun in June 1962 and tests on various Northrop R and D programs began in September 1962. Complete calibration exists at M = 10. Some data has been verified with AEDC results. By August of 1963 there will be 50 channels of thermocouples or 100 channels of pressure instrumentation and on line data reduction will be available.

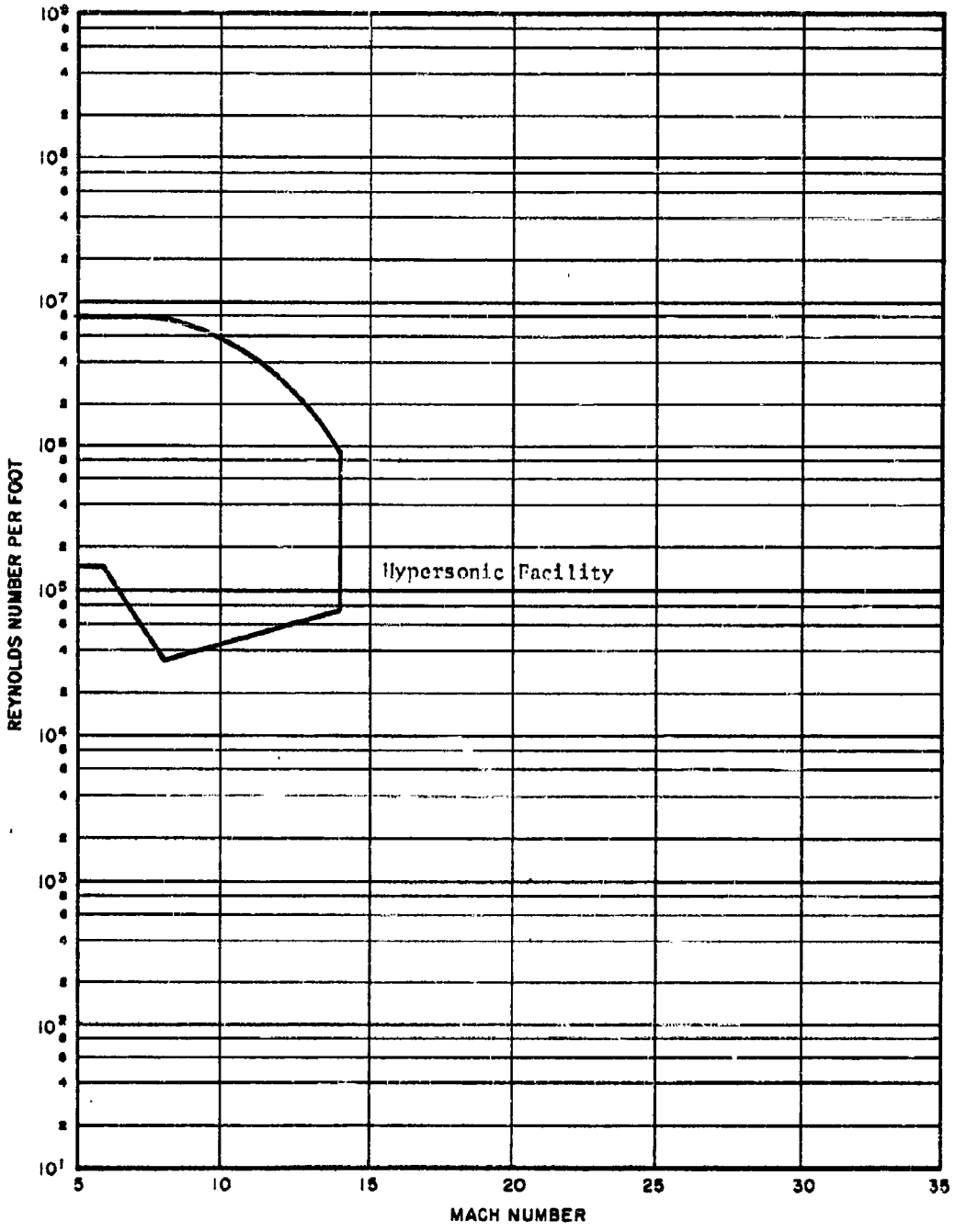
Running Time

Running time in the Norair facility is 25 seconds.

References

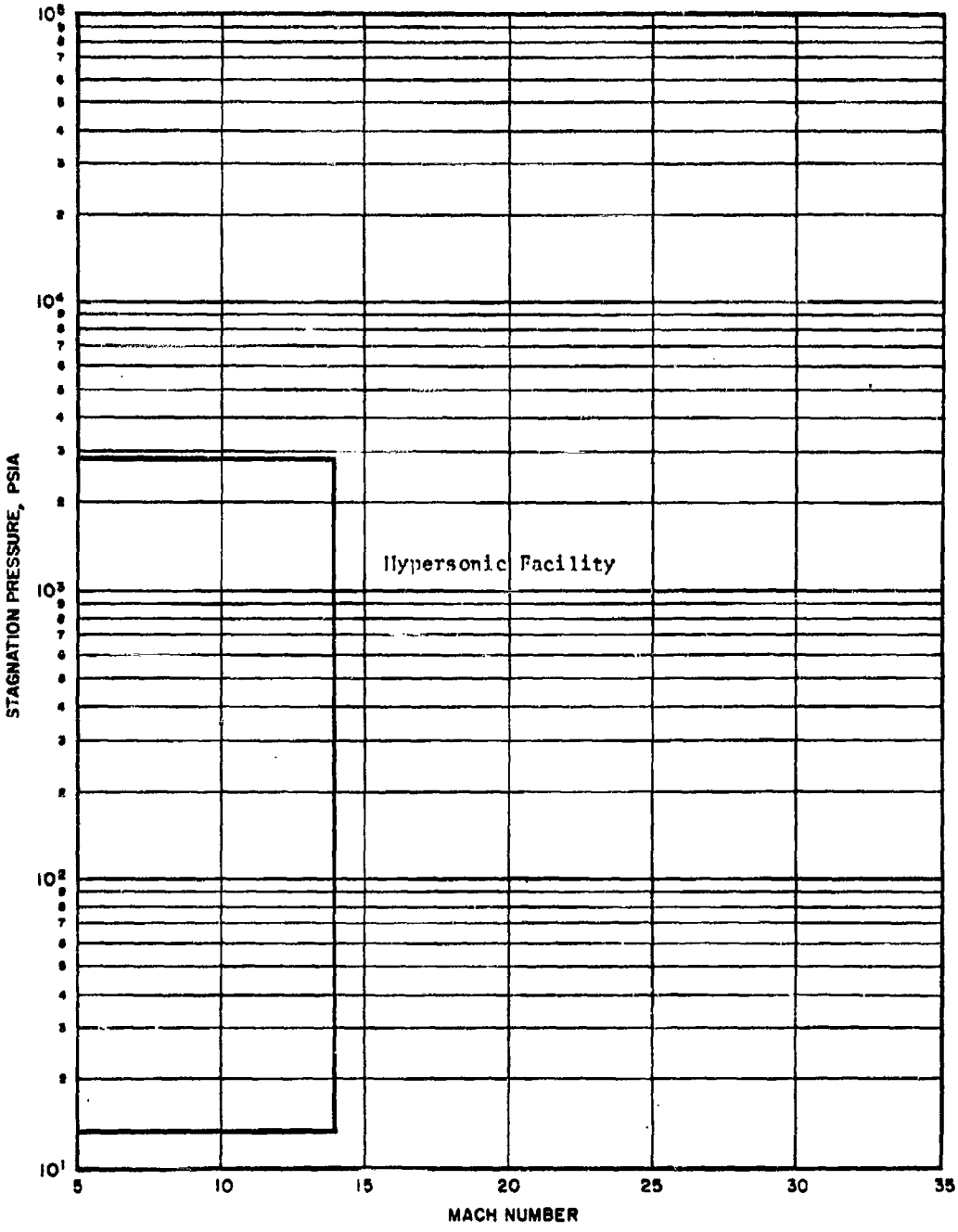
1. "Hypersonic Wind Tunnel", Northrop Corporation brochure, No. NB 62-207, December 1962.

2. Telephone conversation, P. Jensen and N. S. Foy, 14 March 1963.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hypersonic Facility
5
10
15
20
25
30
35

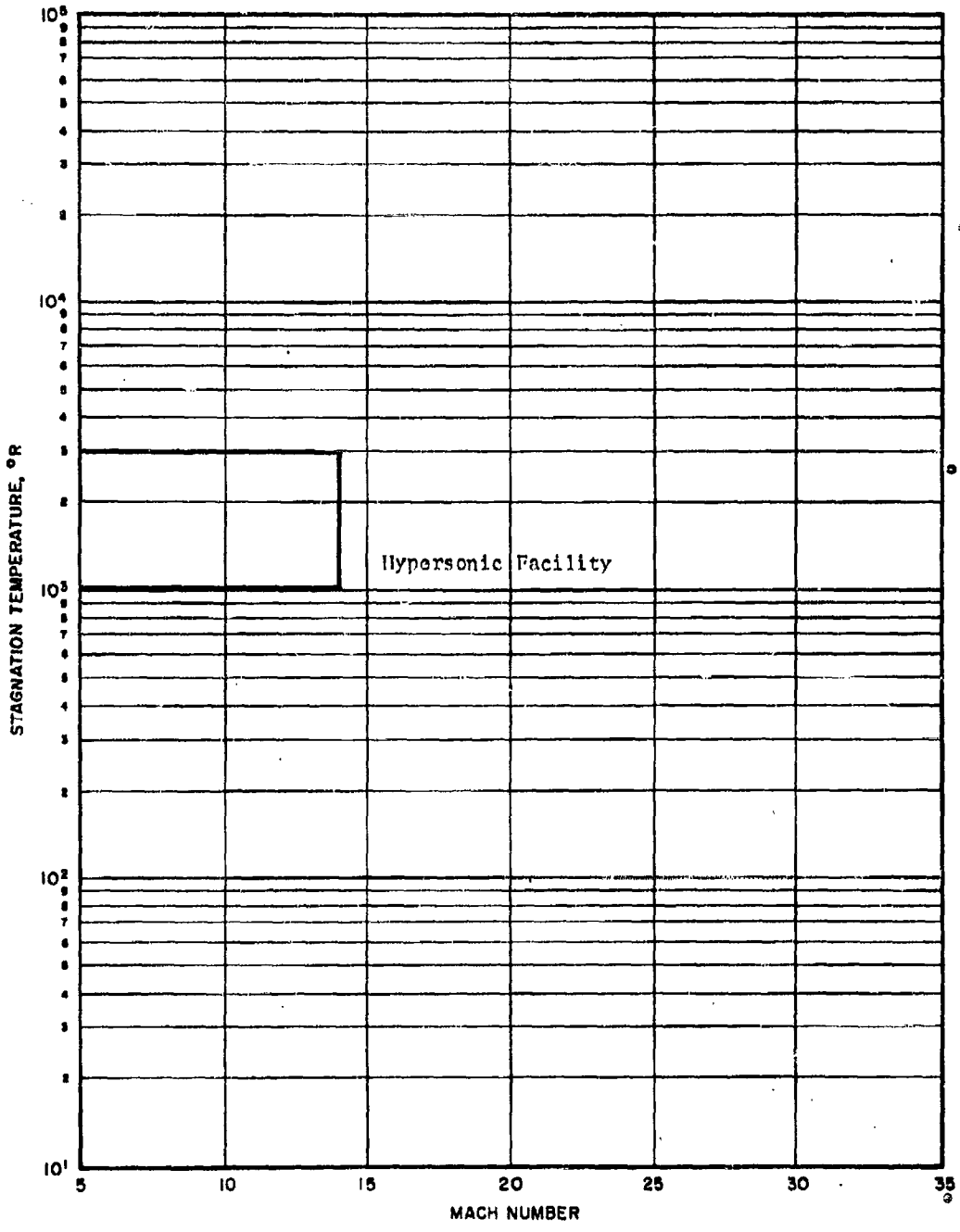
NORTHROP CORPORATION

Norair Division



NORTHROP CORPORATION

Norair Division



Name of Facility

12 Inch Hypersonic Wind Tunnel
The Ohio State University
Aerodynamic Laboratory
Don Scott Field
Columbus 10, Ohio

Person Responsible

Dr. J. D. Lee, Director

Type

The 12 Inch Hypersonic Wind Tunnel is of the continuous type.

Nozzle and Test Section

All nozzles are 12 inches in diameter and contoured. Number 2 nozzle has interchangeable throats for Mach 6, 7 and 8. Number 3 nozzle has throat sections giving it the capability of M = 10, 12.5 and 14. At M = 12.5 the test core has a 7 inch diameter, and at M = 6 it has a 9 inch diameter. The test section is of the free-jet type.

Instrumentation and Test Capability

Temperature, pressure and force can be measured in this facility and automatic data reduction is available. On-the-line analog computer for all measurements provides final corrected data in plotted and tabulated form. An IBM 703 is available on an intermittent basis.

Running Times

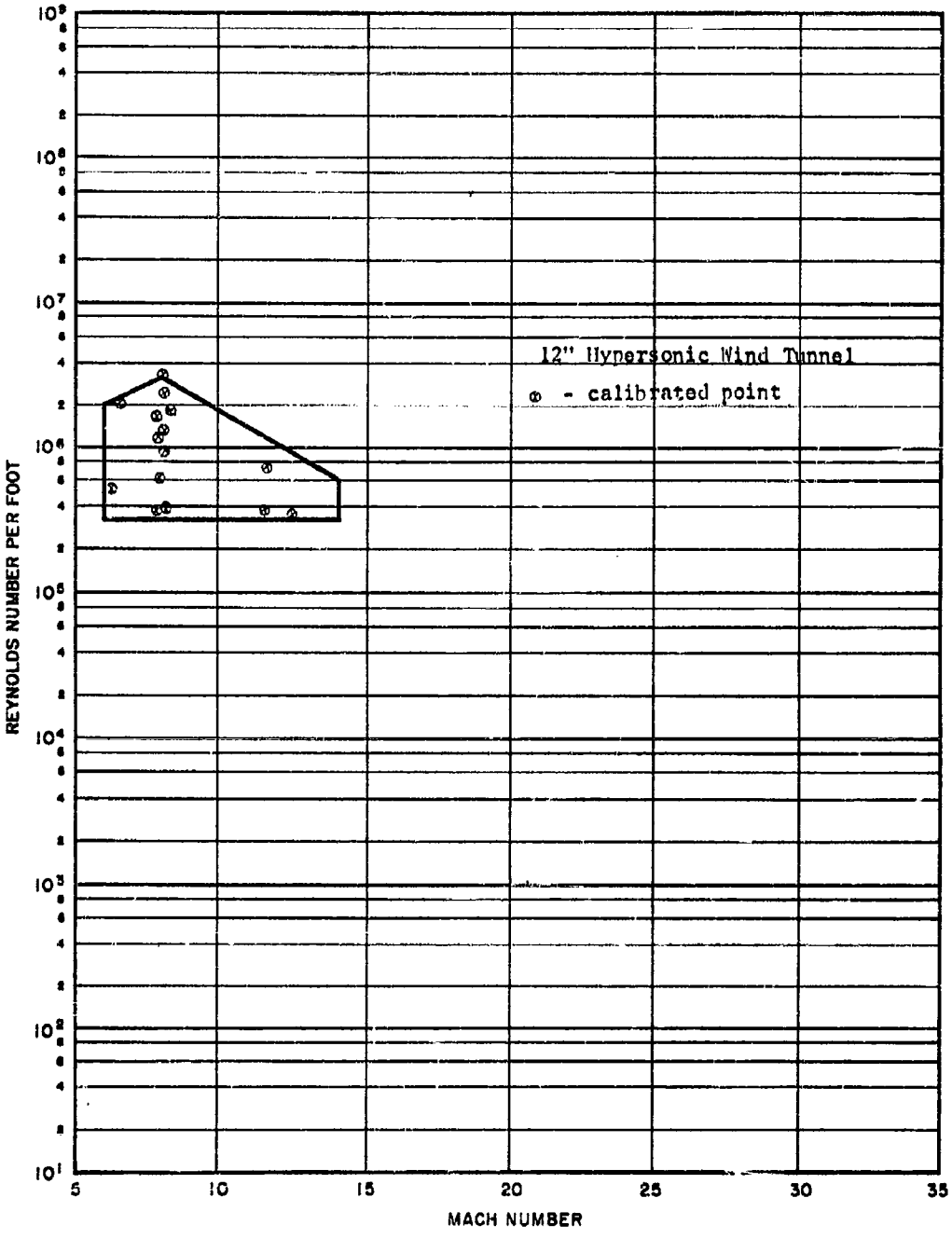
The usual test run is 30 to 60 minutes, though the facility can operate up to 120 minutes for some conditions.

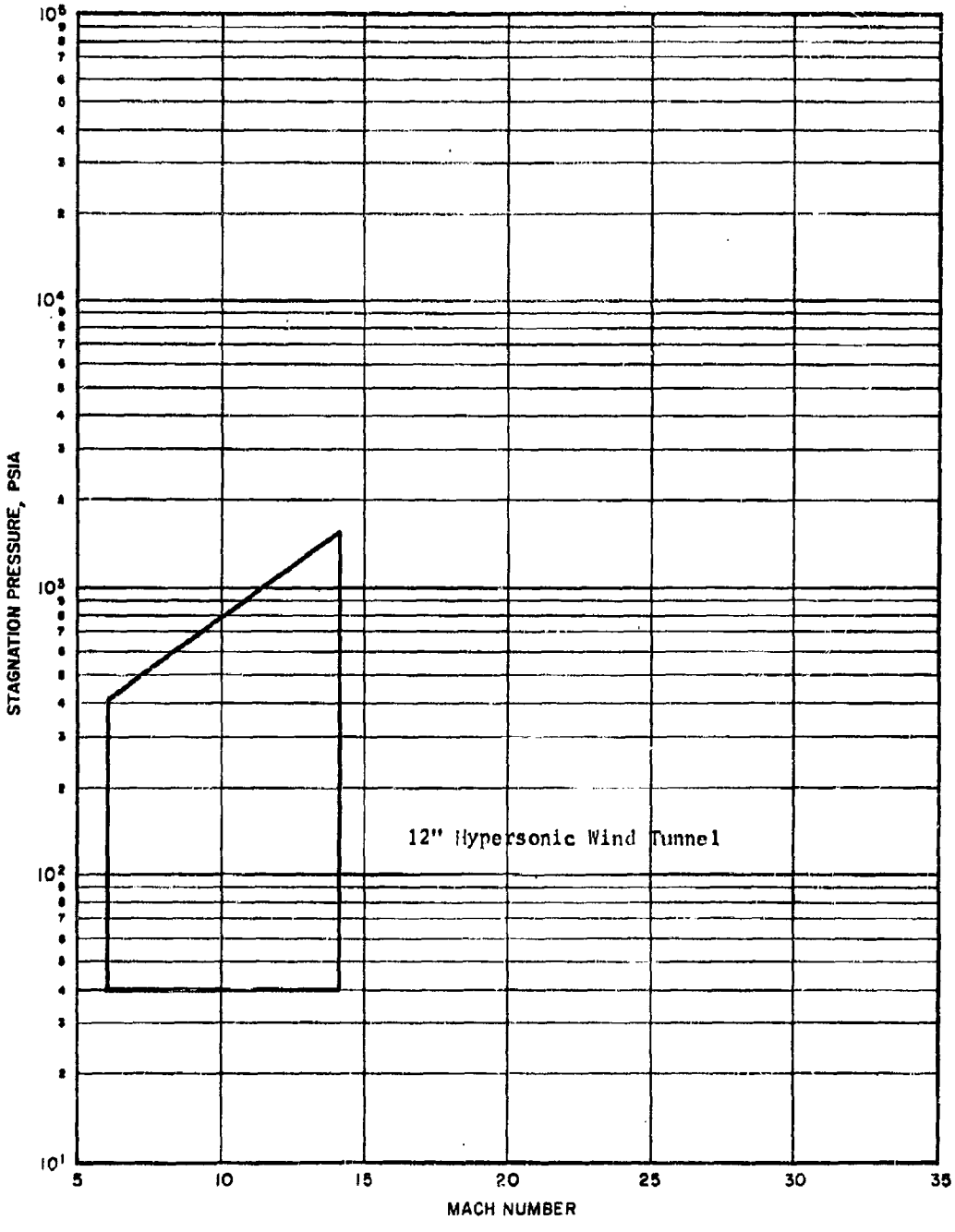
References

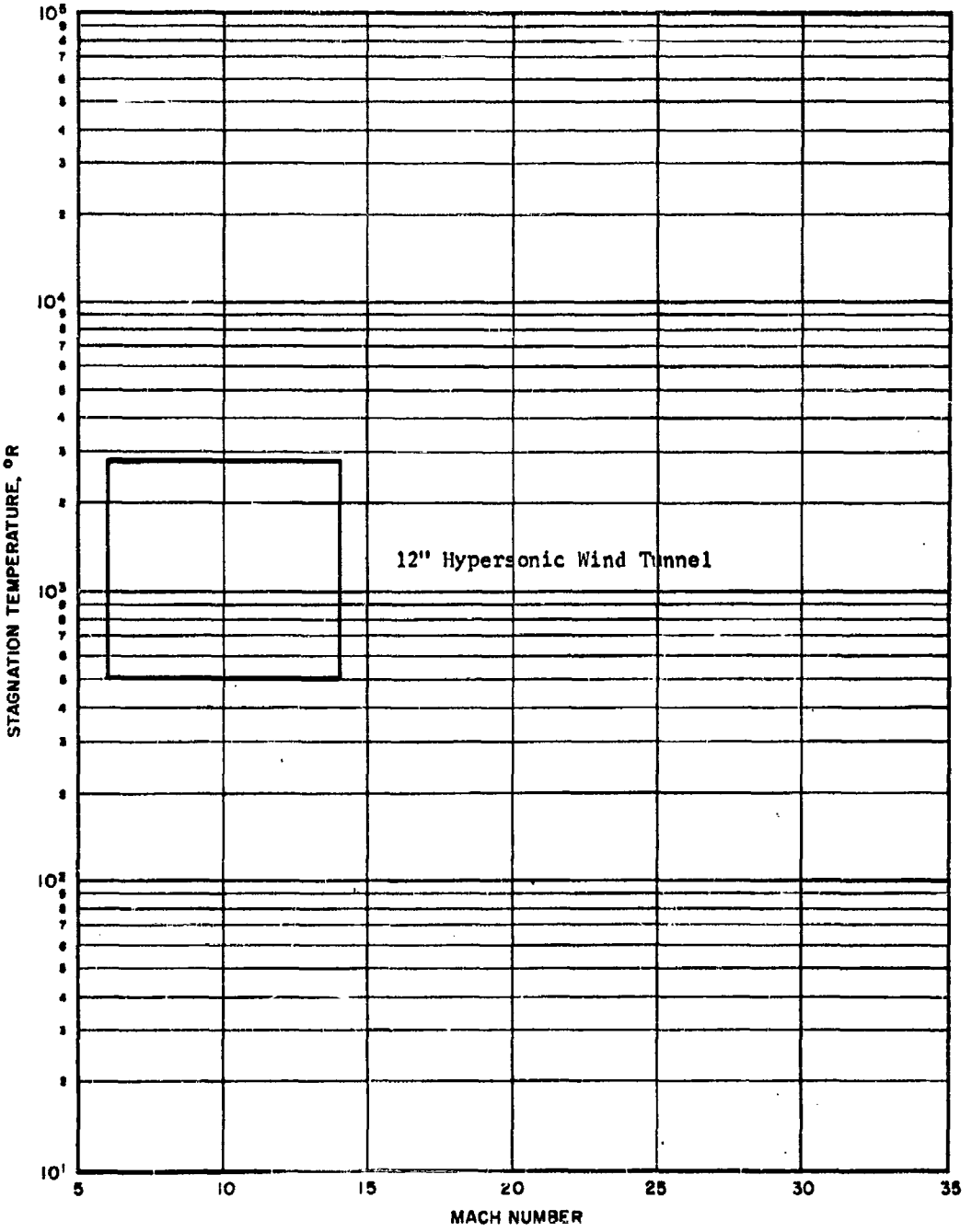
1. "National Wind Tunnel Summary", NASA Report, July 1961.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States". Boeing Report No. D2-5785, April 1960.

3. Letter, Richard E. Thomas to N. S. Foy, dated 17 December 1962, with enclosures.


12" Hypersonic Wind Tunnel
⊗ - calibrated point
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
12" Hypersonic Wind Tunnel


STAGNATION TEMPERATURE, °R
MACH NUMBER
12" Hypersonic Wind Tunnel
5
10
15
20
25
30
35

Name of Facility

Polytechnic Institute of Brooklyn
Aerodynamics Laboratory
Freeport, Long Island, New York

Person Responsible

Dr. Antonio Ferri, Director, Aerodynamics Laboratory

Type

There are two tunnel types at this facility:

A) The Blowdown Hypersonic Wind Tunnels

B) The Shock Tunnel, which is under construction.

Nozzle and Test Section

The hypersonic wind tunnels have contoured nozzles at Mach 4.4, 6, 8 and 12. The test section diameters vary from one foot for the Mach 6 tunnel to roughly four feet for the Mach 12 tunnel.

Instrumentation and Test Capabilities

Force, pressure and heat transfer data may be obtained in the hypersonic wind tunnels. The M = 12 tunnel has been operational for two years, and the shock tunnel is in the construction stage.

Running Times

A) Blowdown Hypersonic Wind Tunnels - 15 seconds to one minute.

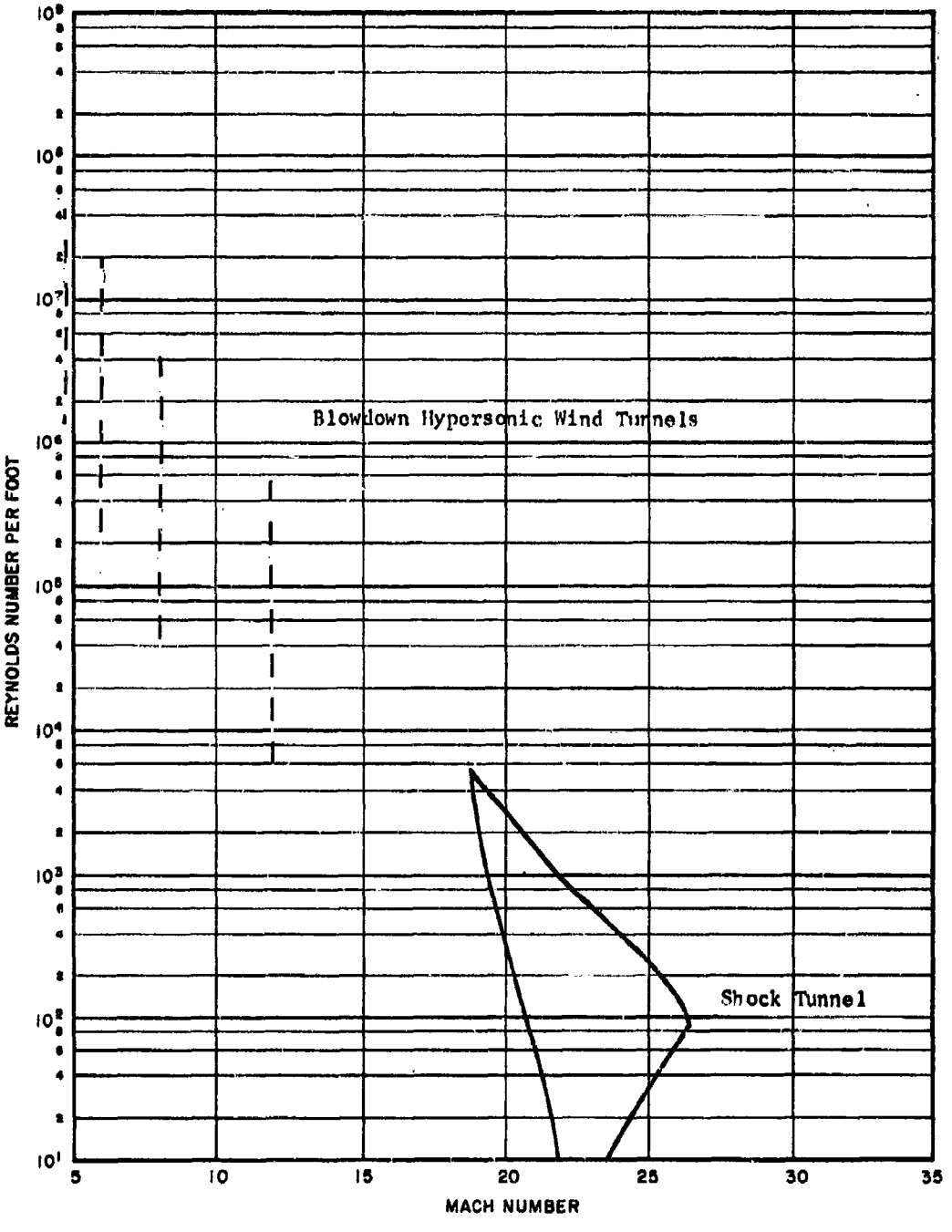
B) Shock Tunnel - will be on the order of 4 milliseconds.

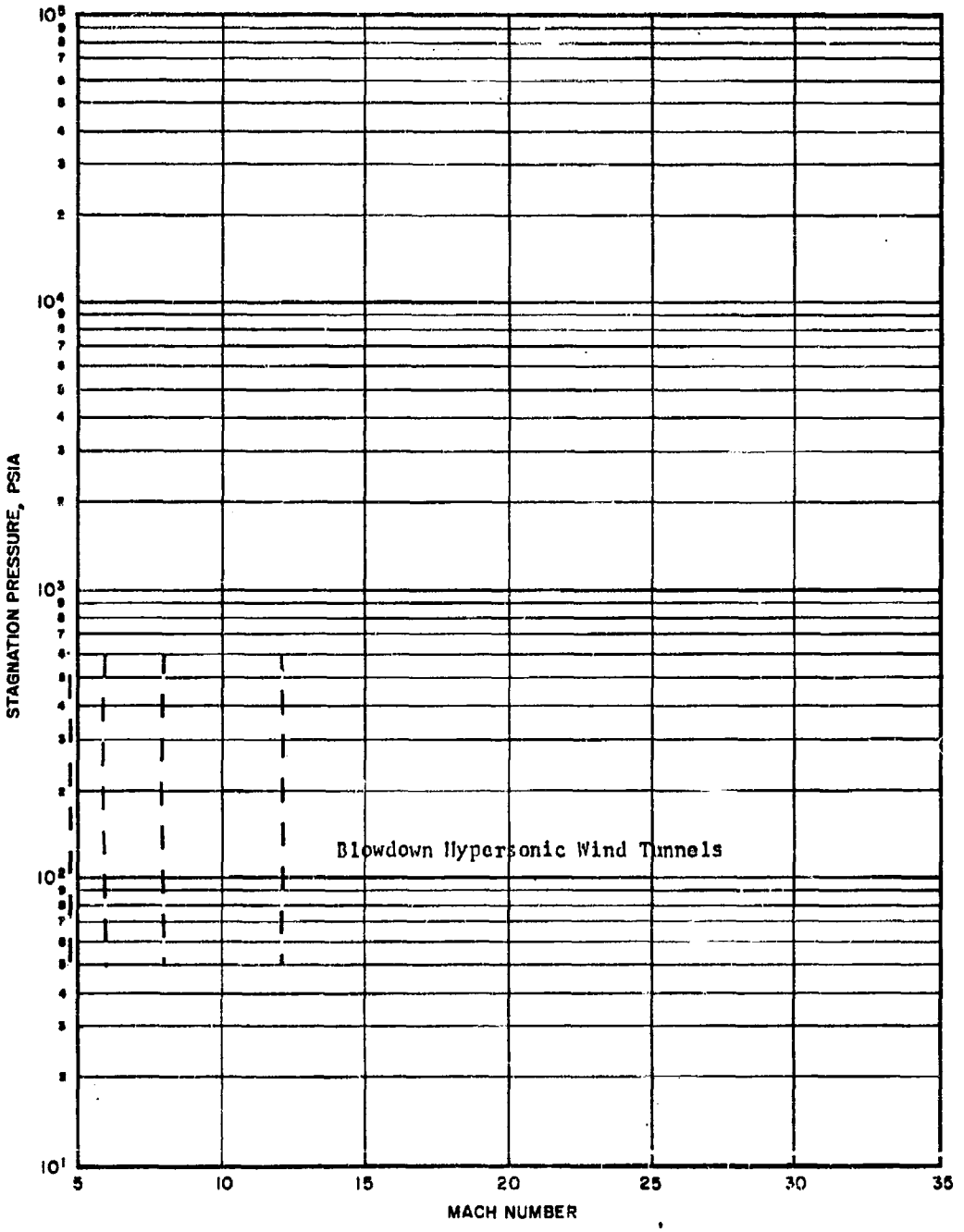
References

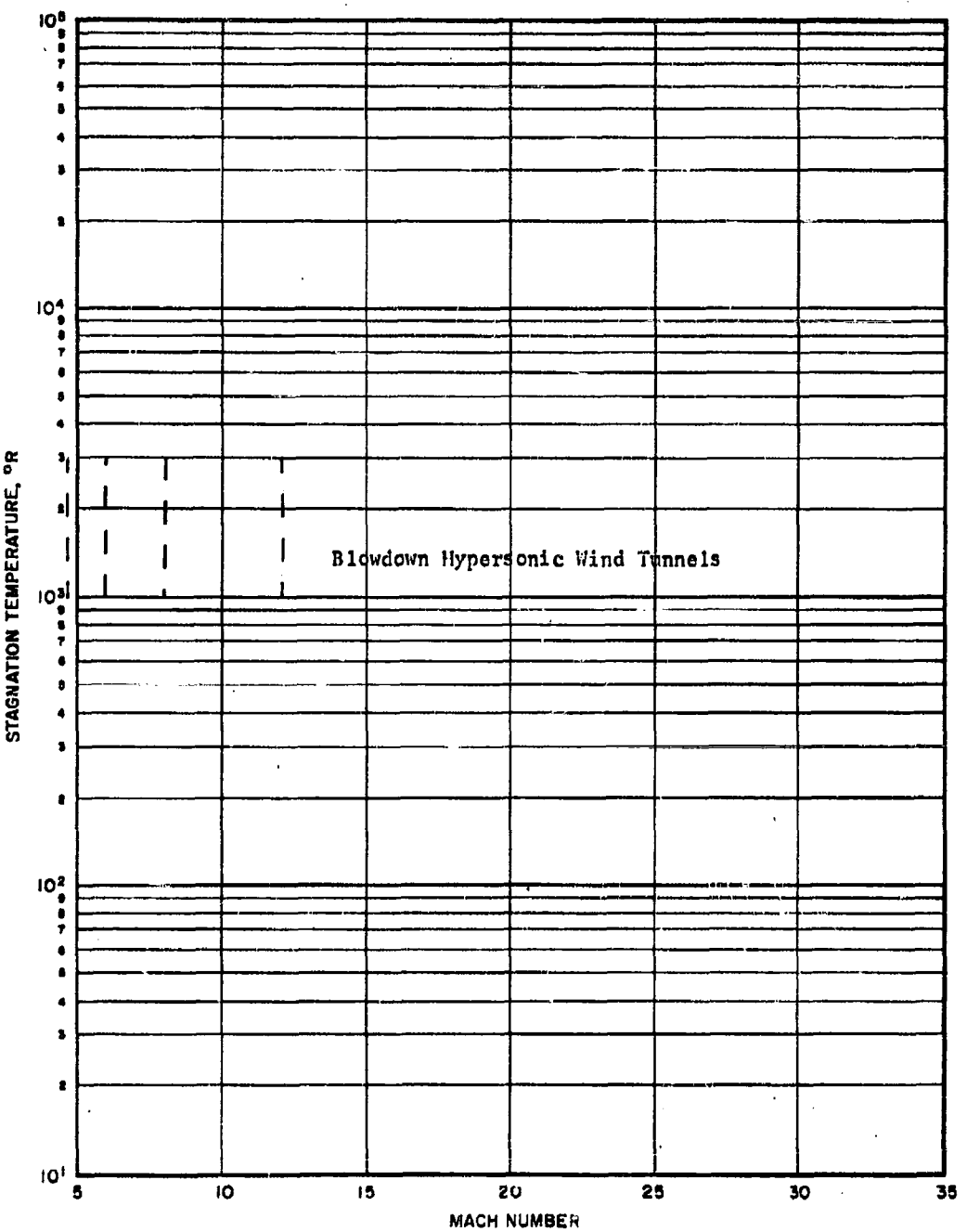
1. "Aerodynamic Analysis of a Low-Density Hypersonic Shock-Wind Tunnel", by S. Panunzio and F. Vicente, PIBAL Report, September 1960.

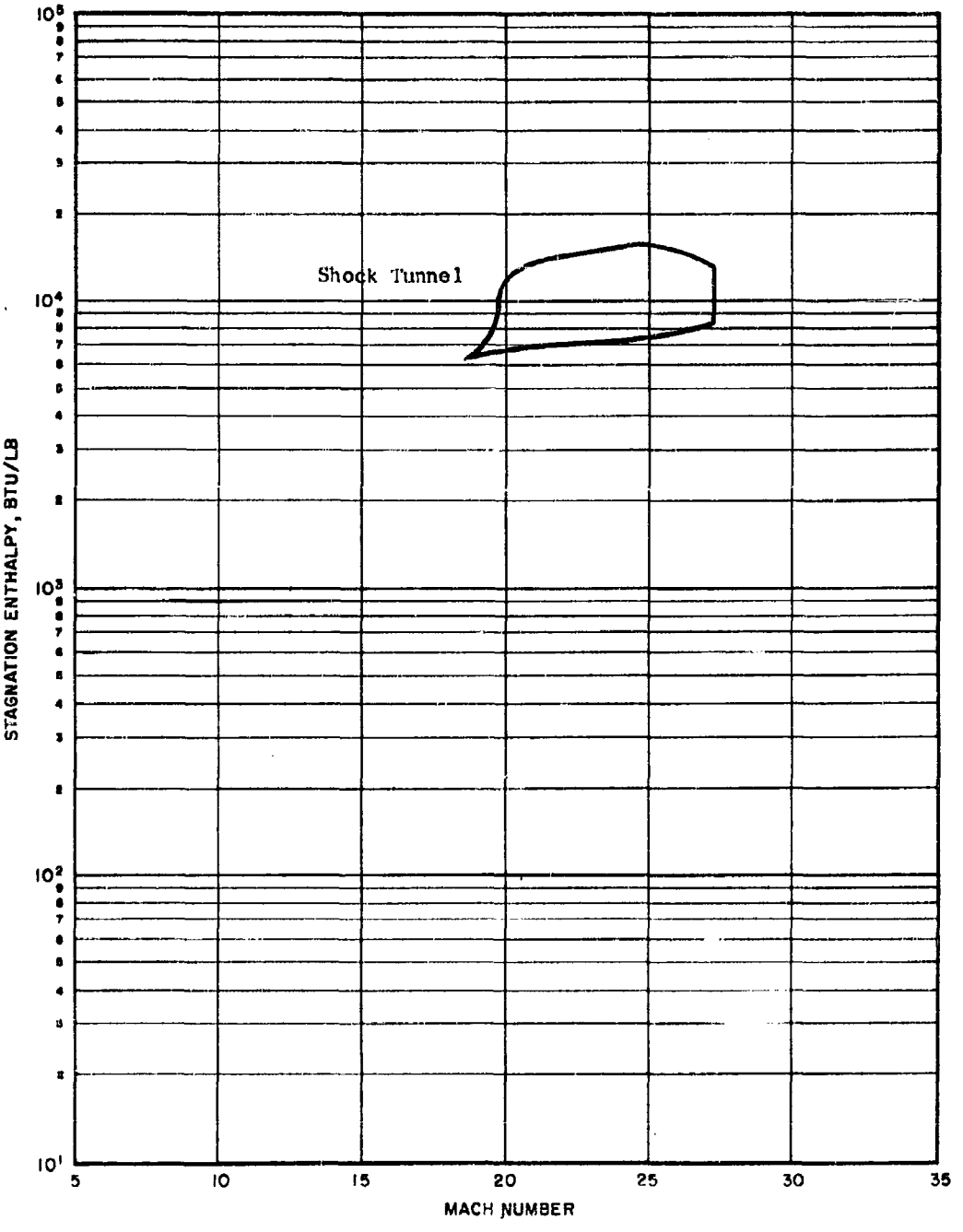
2. "National Wind Tunnel Summary", NASA Report, July 1961.

3. Letter, Dr. Marian Visich, Jr. to N. S. Foy, dated 4 January 1963, with enclosures.


Blowdown Hypersonic Wind Tunnels
Shock Tunnel
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
5
10
15
20
25
30
35
Blowdown Hypersonic Wind Tunnels


STAGNATION TEMPERATURE, °R
MACH NUMBER
Blowdown Hypersonic Wind Tunnels


Shock Tunnel
STAGNATION ENTHALPY, BTU/LB
MACH NUMBER
10⁵
10⁴
10³
10²
10¹
5
10
15
20
25
30
35

Name of Facility

Princeton University
The James Forrestal Research Center
Gas Dynamics Laboratory
Building 5A, Box 710
Princeton, New Jersey

Person Responsible

Seymour M. Bogdonoff, Professor of Aeronautical Engineering

Type

Four facilities of the intermittent type are available at Princeton. They are:

A) The 3 Inch Helium Hypersonic Wind Tunnel

B) The 6 Inch Helium Hypersonic Wind Tunnel

C) The 3 Inch Heated Air Tunnel

D) The 5 Inch Nitrogen Tunnel, which uses graphite as a heater element

Nozzle and Test Section

A) The 3 inch helium hypersonic wind tunnel has several conical nozzles, giving flow Mach numbers from 7 to 24. Several contoured nozzles for uniform flow are available for Mach numbers that range from 8 to 20. The core diameter is 2 inches.

B) The 6 inch helium hypersonic tunnel has two nozzles; one conical with a Mach number range from 15 to 17 and the other contoured with a Mach number of 16. The usable core is about 4 inches with both nozzles.

C) The heated air tunnel has a 3 inch diameter test section with a 2 inch diameter core. A contoured nozzle for Mach 10 is available as well as conical nozzles for Mach numbers from 7 to 10.

D) The nitrogen tunnel has a conical nozzle with a 5 inch exit diameter. A Mach number of 15 is obtained in the test section with a core diameter of about 2.5 inches.

Instrumentation and Test Capabilities

Temperature and pressure measurements can be made in all of the Princeton facilities.

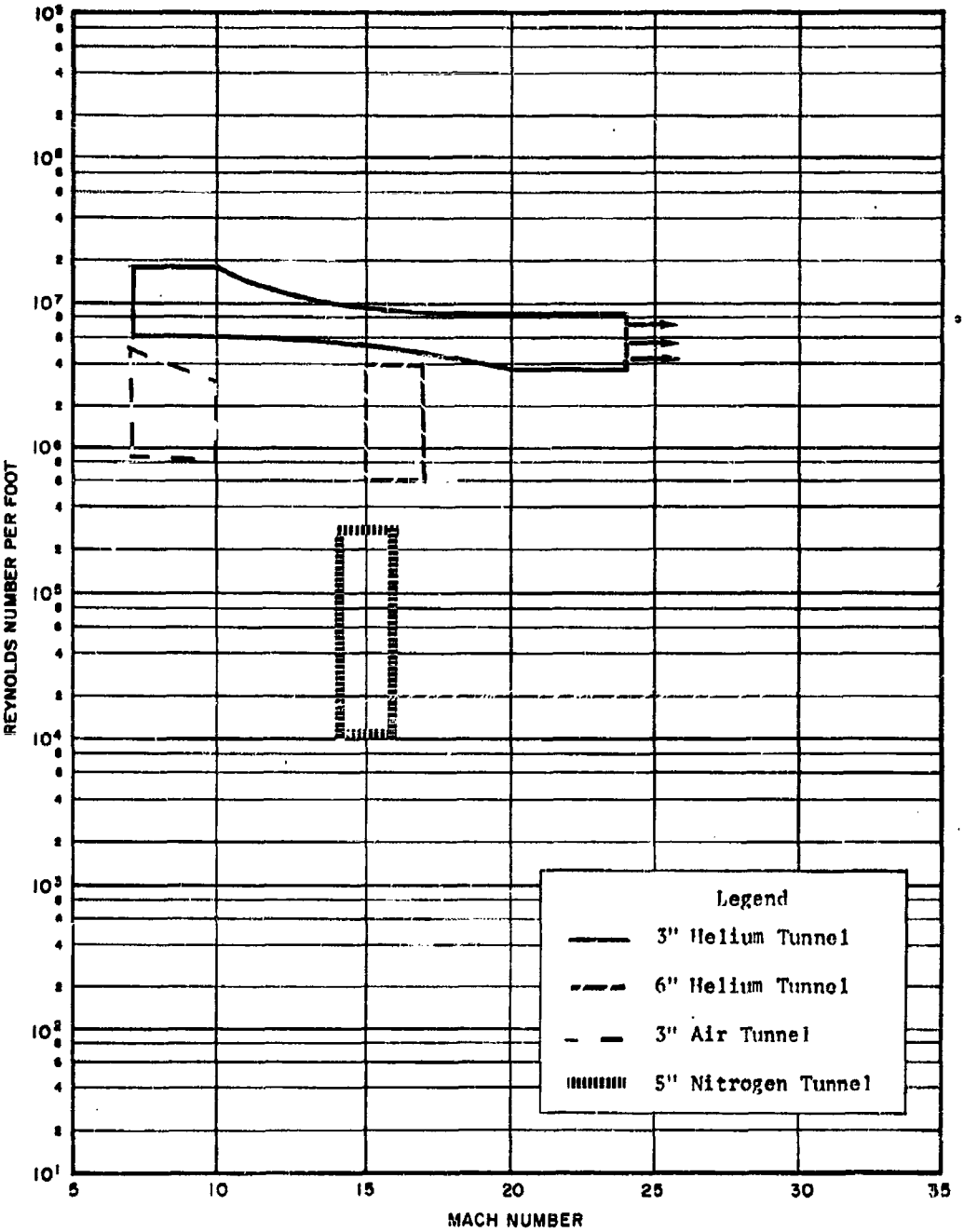
Running Times

The helium wind tunnels, as well as the air tunnel, have running times up to 10 minutes, with a total run time of 30 minutes per day. The nitrogen tunnel has a running time of 20 minutes with a total run time exceeding one hour per day.

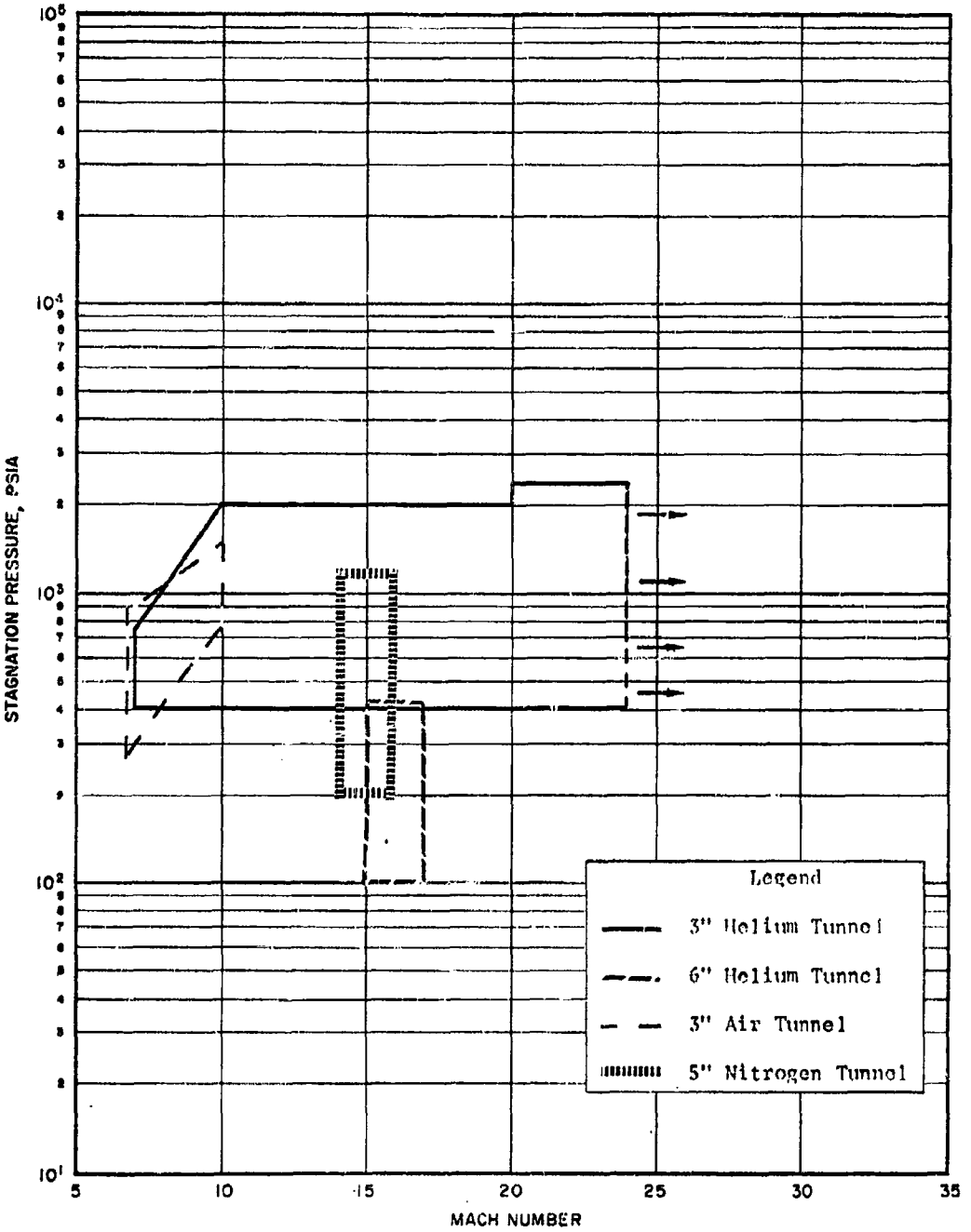
References

1. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels In the United States", Boeing Report No. D2-5785, April 1960.

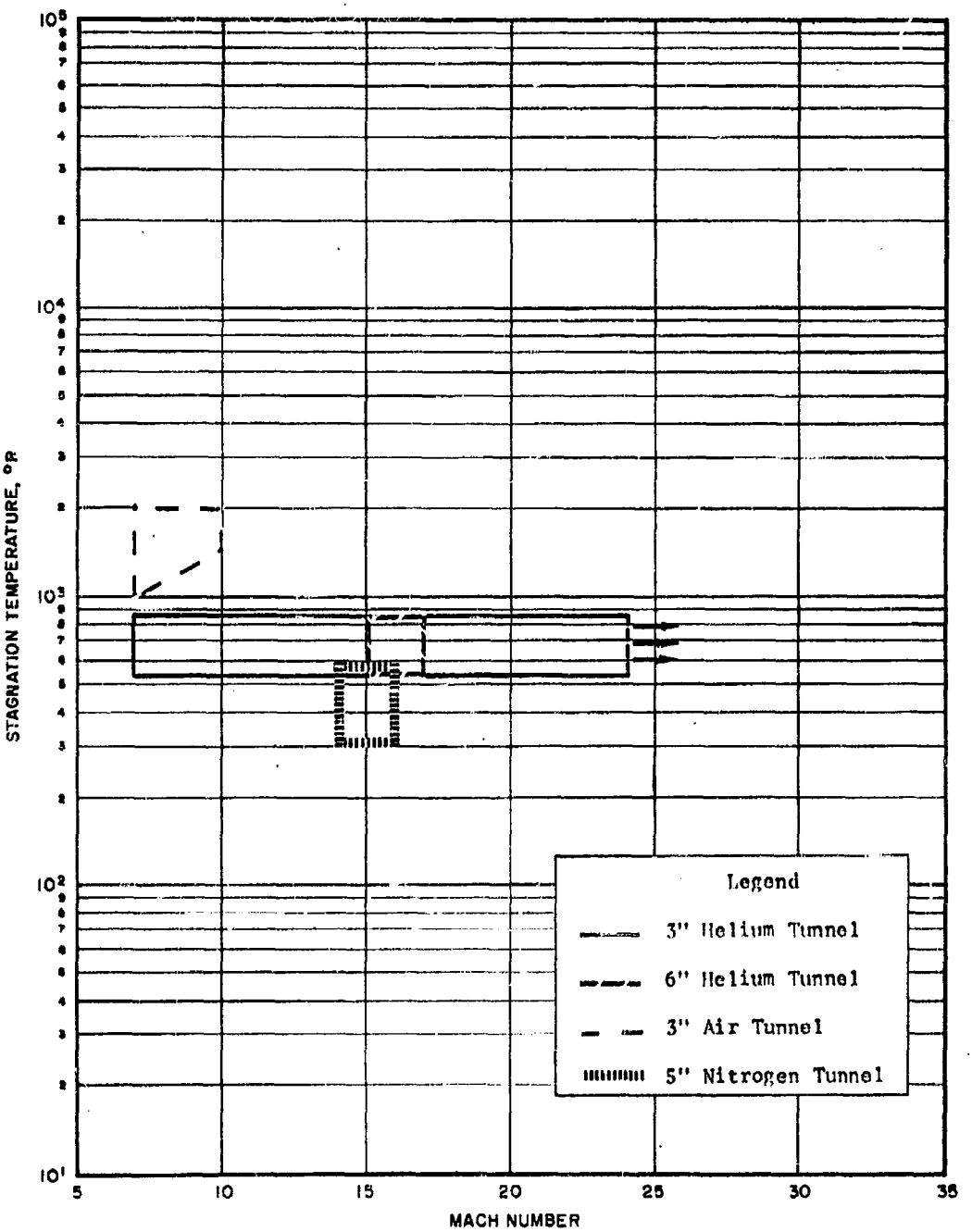
2. Letter, Irwin E. Vas to N. S. Foy, dated 28 December 1962, with enclosures.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35
Legend
3" Helium Tunnel
6" Helium Tunnel
3" Air Tunnel
5" Nitrogen Tunnel

PRINCETON UNIVERSITY



PRINCETON UNIVERSITY



Name of Facility

Republic Paul Moore Research and Development Center
Republic Aviation Corporation
Farmingdale, Long Island, New York

Person Responsible

Mr. H. Lu

Type

Two hypersonic facilities are in the shakedown and calibration stages at Republic Aviation. These are:

A) A blowdown 36 inch Hypersonic Wind Tunnel, utilizing a gas fired pebble bed heater.

B) The combustion-driven Hypervelocity Wind Tunnel, which is a 24 inch shock tunnel.

The Hypersonic Wind Tunnel is under calibration, while the Hypervelocity Wind Tunnel is in the shakedown stage, with stagnation pressure at the 40,000 psi level. Both facilities are expected to become operational during 1963.

Nozzle and Test Section

A) The Hypersonic Wind Tunnel will use a contoured nozzle expanding into a 36 inch test section.

B) The Hypervelocity Wind Tunnel uses a conical nozzle expanding into a 24 inch test section.

Instrumentation and Test Capabilities

Force, pressure and heat transfer test capabilities are planned for the Republic Aviation facilities.

Running Times

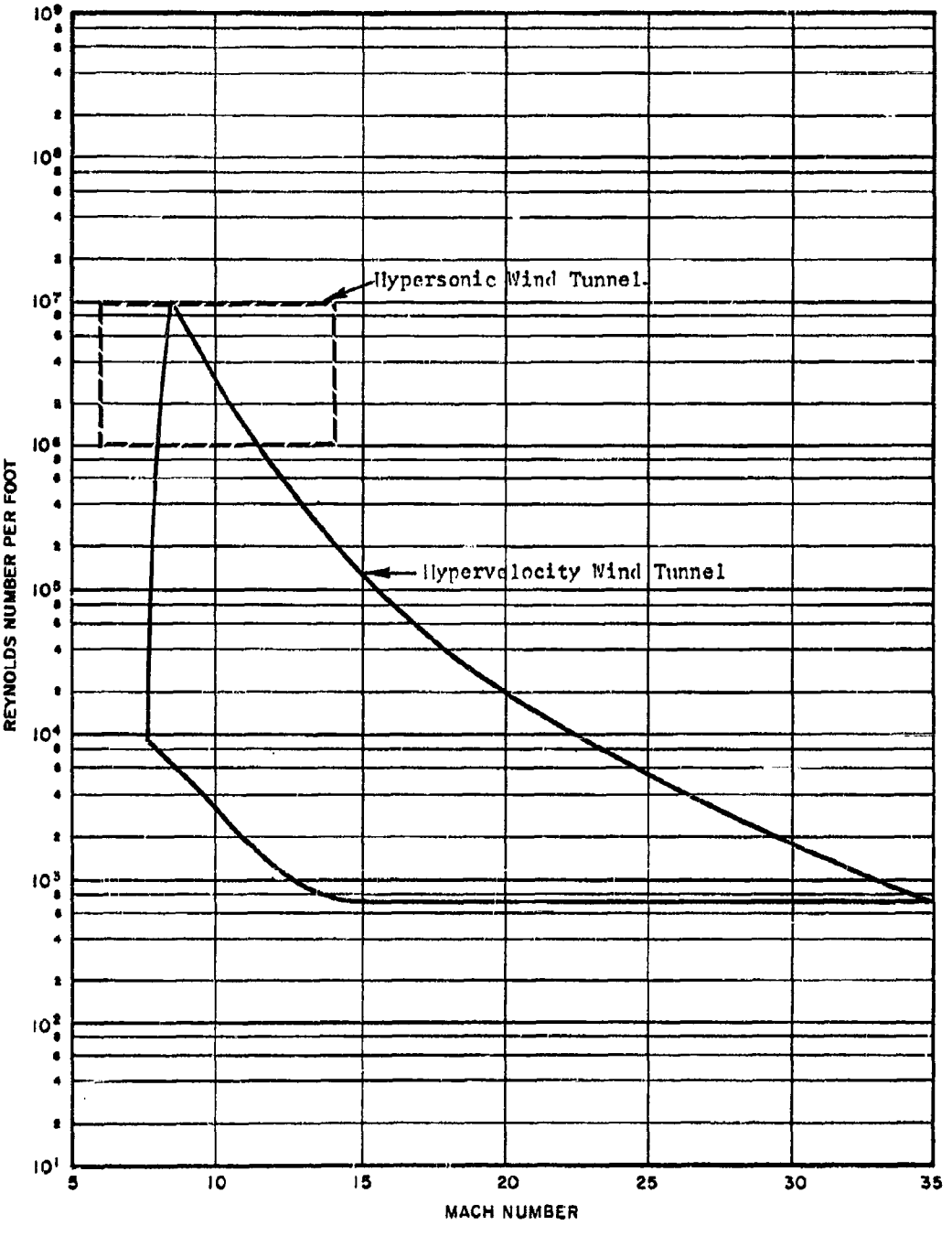
The Hypersonic Wind Tunnel has a maximum running time at M = 6 of 30 seconds.

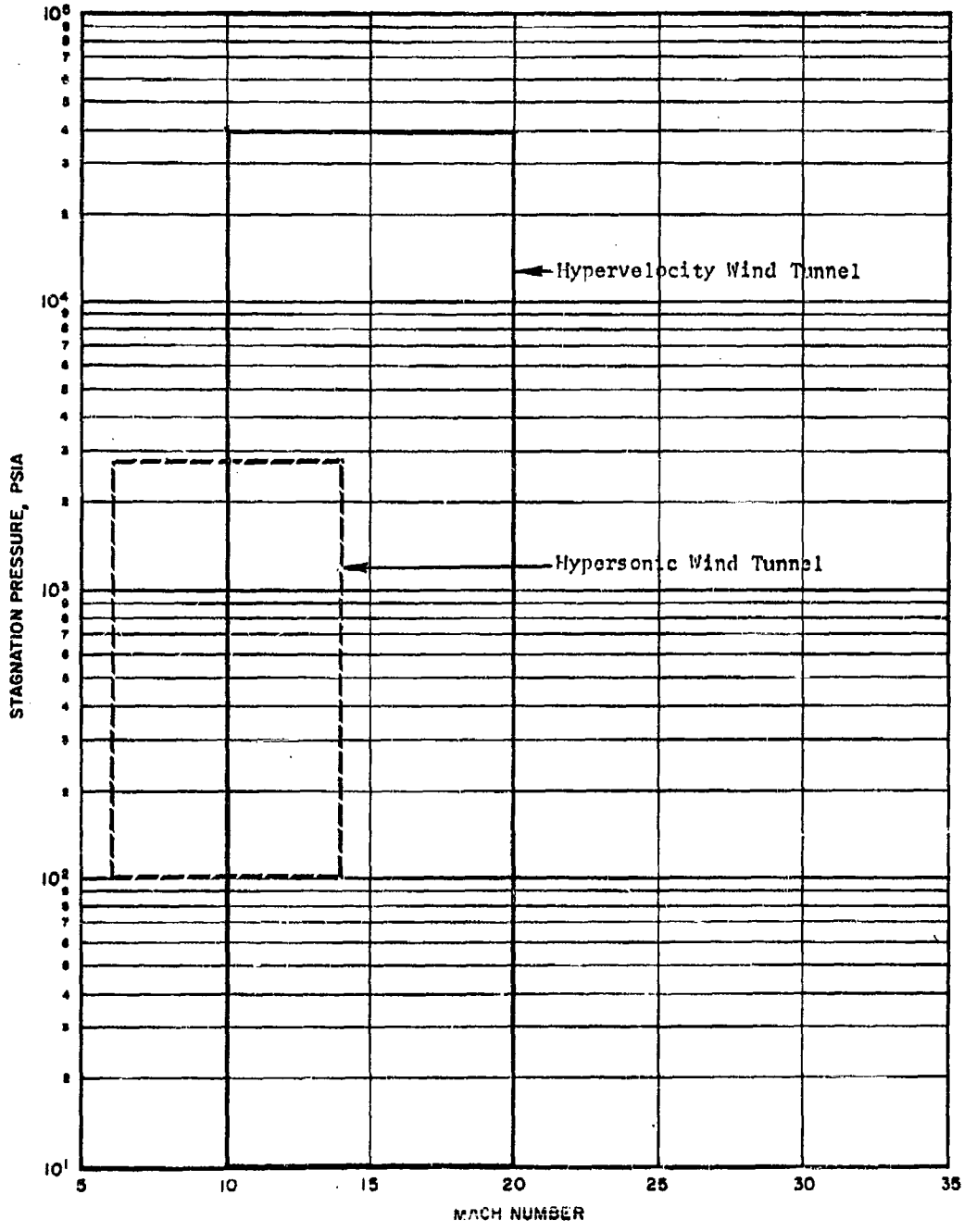
References

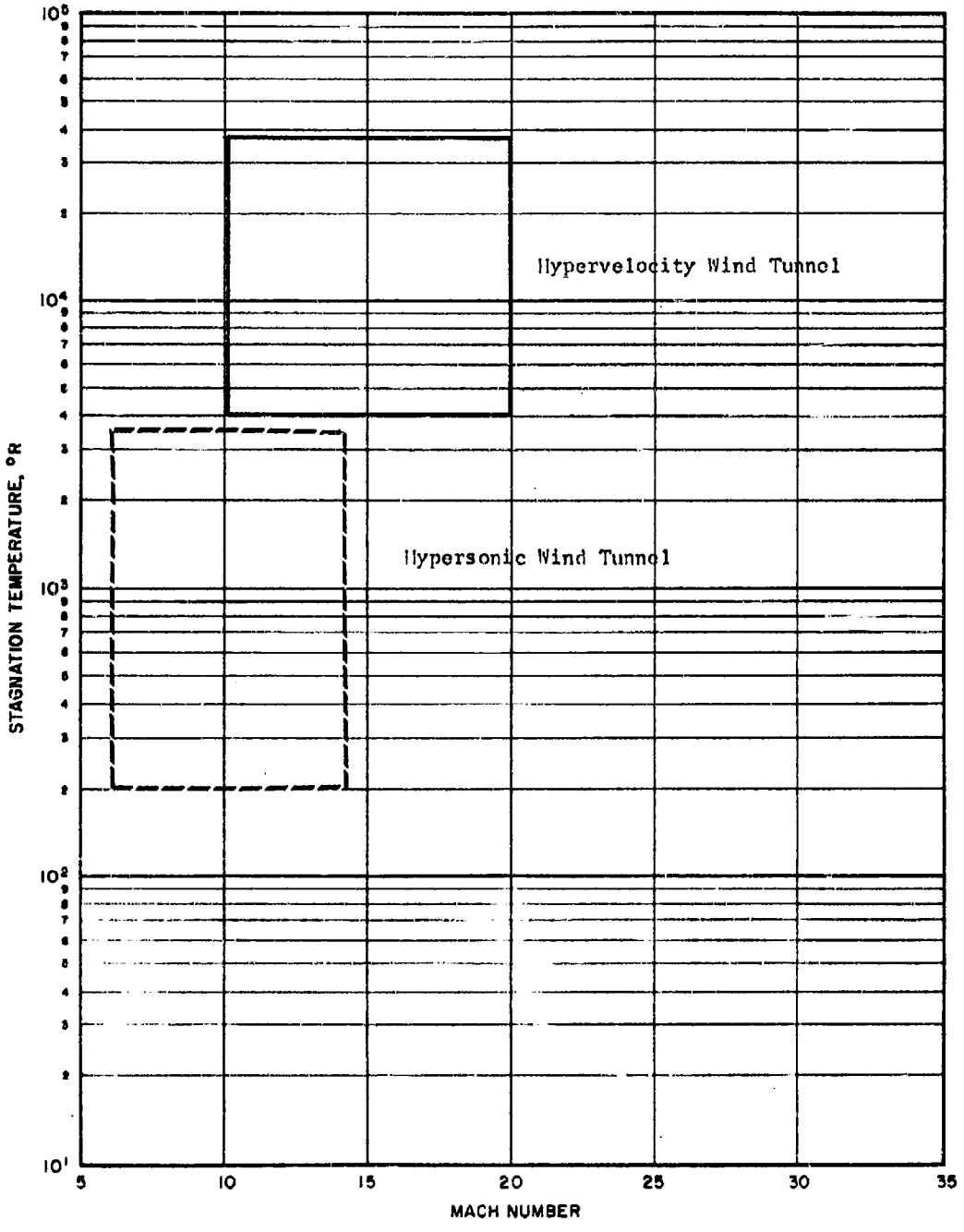
1. "Aerodynamic Testing Facilities at Republic Aviation Corporation", brochure.

2. "Republic 24-Inch Hypervelocity Wind Tunnel", brochure.

3. Letter, H. Lu to N. S. Foy, dated January 1963, with enclosures.


Hypersonic Wind Tunnel
Hypervelocity Wind Tunnel
REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
10
15
20
25
30
35


Hypervelocity Wind Tunnel
Hypersonic Wind Tunnel
STAGNATION PRESSURE, PSIA
MACH NUMBER
5
10
15
20
25
30
35


Hypervelocity Wind Tunnel
Hypersonic Wind Tunnel
STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

60 Inch Hypervelocity Tunnel
Rhodes and Bloxsom
7343 Deering Avenue
Canoga Park, California

Persons Responsible

D. Bloxsom, Jr.
B. V. Rhodes

Type

The 60 Inch Hypervelocity Tunnel is an arc driven hotshot, utilizing a 100,000 joule capacitor. It was built in 1959.

Nozzle and Test Section

The nozzle is a conical one, expanding to a 5 to 60 inch diameter test section.

Instrumentation and Test Capabilities

Simultaneous measurements have been made of pressure, temperature and density within millisecond intervals. Ballistic mounting of models has permitted lift and drag coefficients to be measured to 1% accuracy, in gas dynamic to free molecule flow.

Running Time

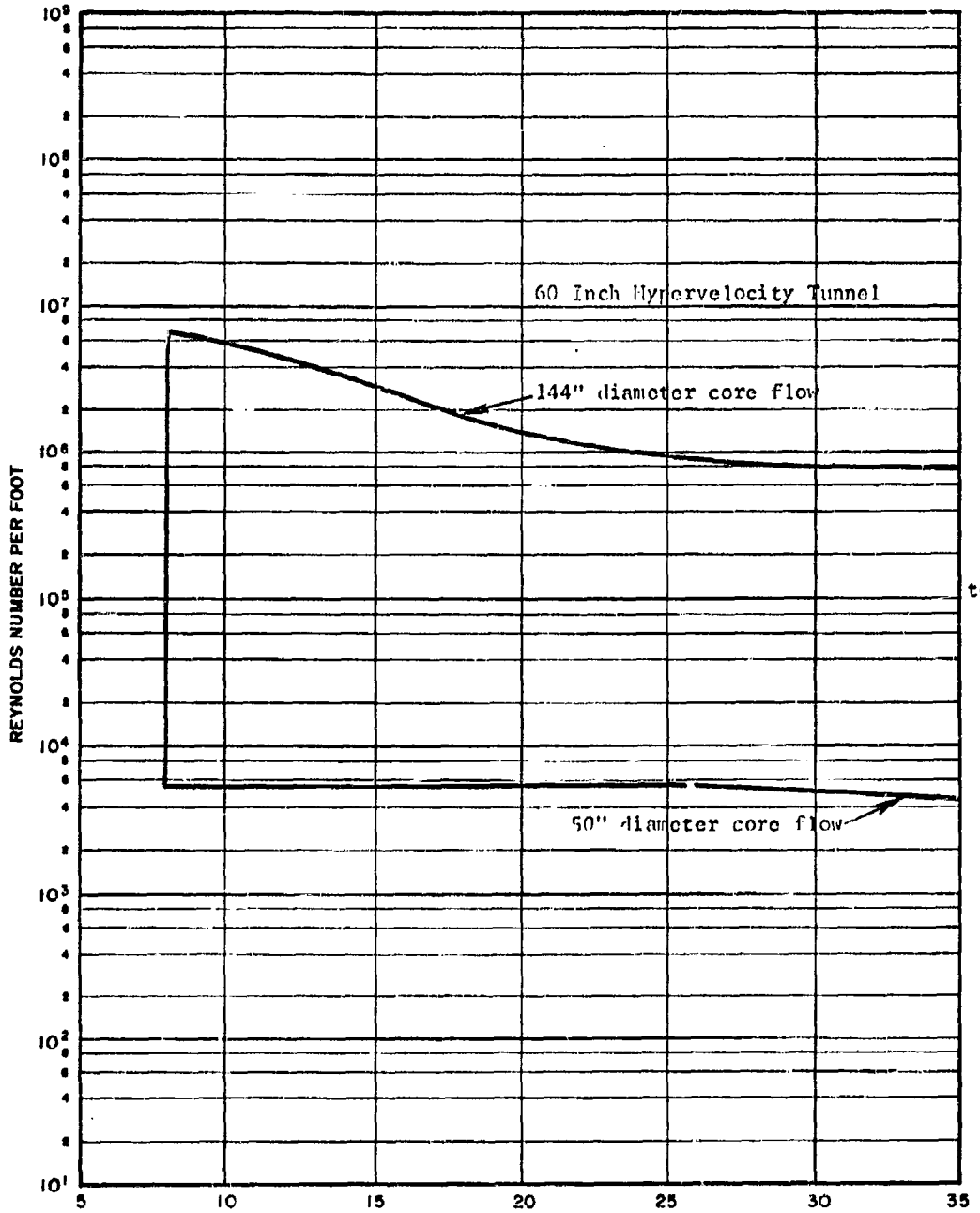
Test time varies from 1 to 100 milliseconds.

References

1. Calibration Brochure, Rhodes and Bloxsom, October 1961.

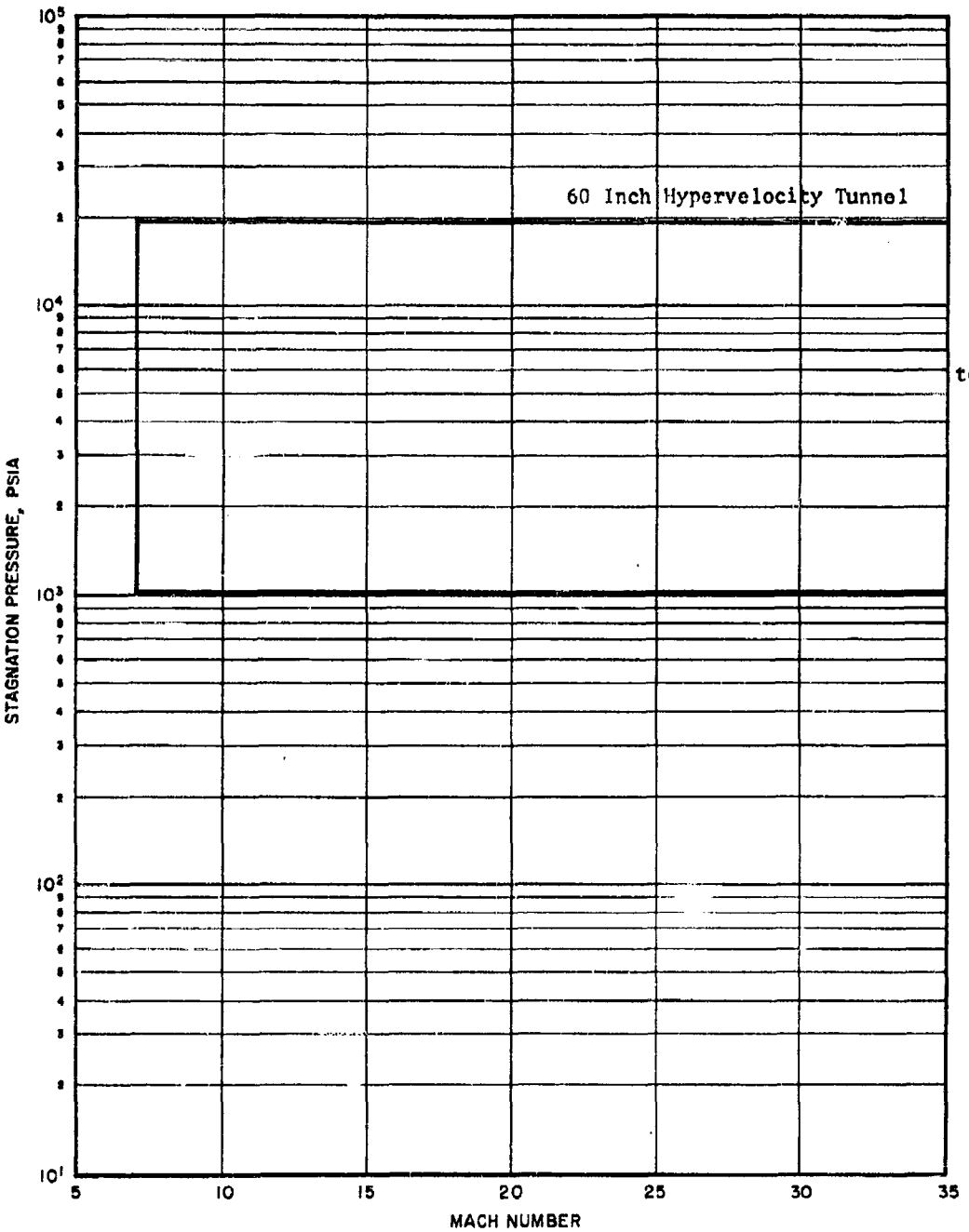
2. "Hypersonic Aerodynamic Experiments Using Very High Temperature Air Wind Tunnels", Rhodes and Bloxsom, December 1962.

3. Letter, D. Bloxsom, Jr., to N. S. Foy, dated 17 December 1962, with enclosures.

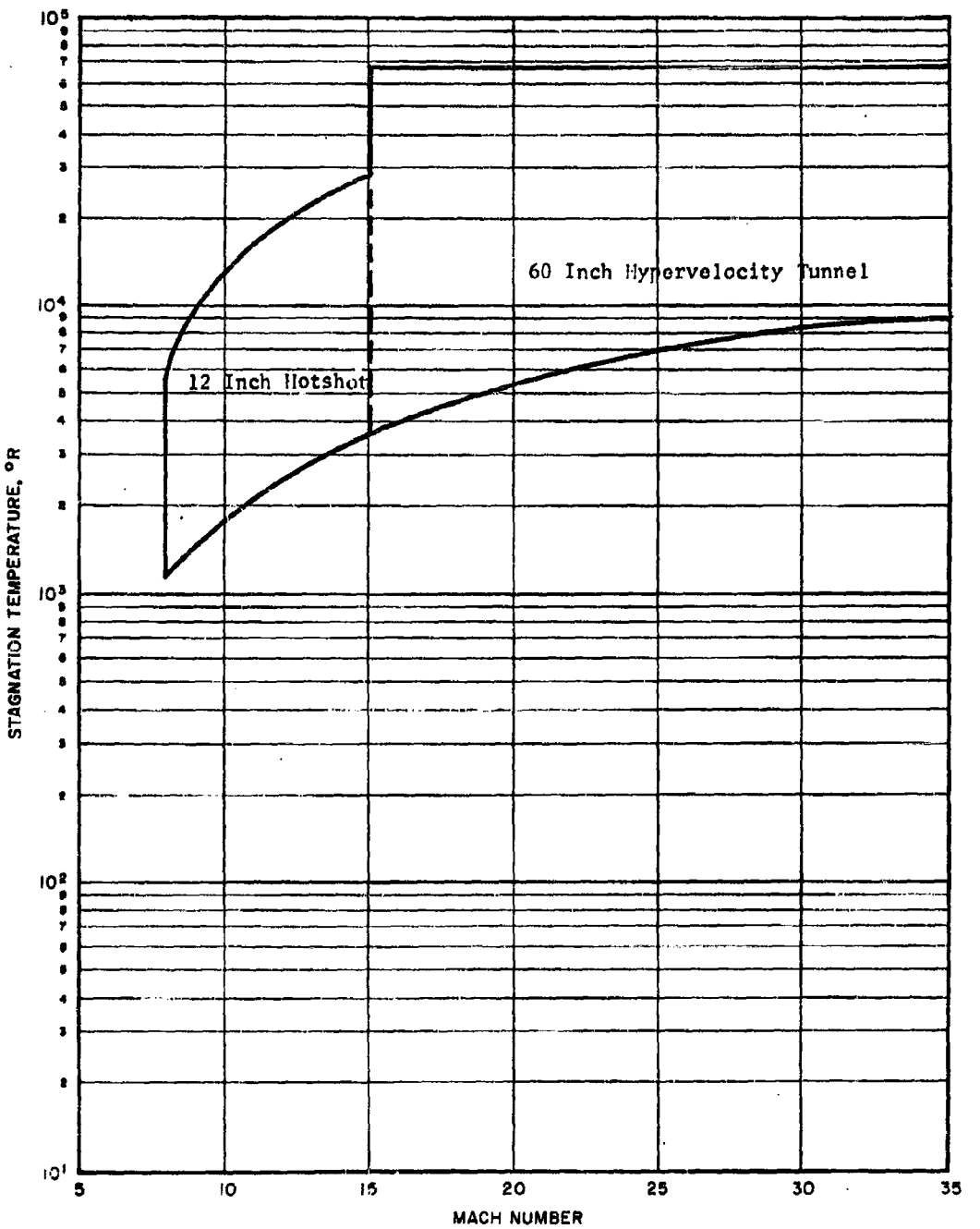


to M = 60

At Full Enthalpy


60 Inch Hypervelocity Tunnel
STAGNATION PRESSURE, PSIA
MACH NUMBER
10^5
10^4
10^3
10^2
10^1
5
10
15
20
25
30
35

to M = 60


STAGNATION TEMPERATURE, °R
MACH NUMBER
60 Inch Hypervelocity Tunnel
12 Inch Hotshot
5
10
15
20
25
30
35

to M = 60

Name of Facility

Rosemount Aeronautical Laboratories
University of Minnesota
Rosemount, Minnesota

Persons Responsible

Mr. Karl Stefan - Tunnel No. 2

Dr. Rudolph Hermann - Tunnel No. 4

Type

Two intermittent facilities are available at Rosemount. They are:

A) Tunnel No. 2

B) Tunnel No. 4

Nozzle and Test Section

A) Tunnel No. 2 has a two-dimensional M= 7 contoured nozzle and a closed jet test section with a 12 by 12 inch rectangular cross-section. At maximum Mach number the test core is 8 by 8 inches, and at minimum Mach number it is 10 by 10 inches, a 3 inch cruciform model has been successfully tested.

B) Tunnel No. 4 has a two-dimensional M = 7 contoured nozzle and a square closed jet test section of 12 inches. Its test core is 8 by 8 inches. Models which have been successfully tested include a 6 inch diameter 10° half angle cone, a 4 inch diameter hemisphere-cylinder and an 8 by 12 inch flat plate.

Instrumentation and Test Capabilities

Temperature, pressure and force can be tested in both facilities. Recording traces and manometer boards are read manually. The laboratory has an LPG-30 computer, which is generally utilized for pressure or force coefficients and integration of pressure to get lift, drag or moment. Single and double pass Schlieren systems are available, as well as Fastax camera.

Running Times

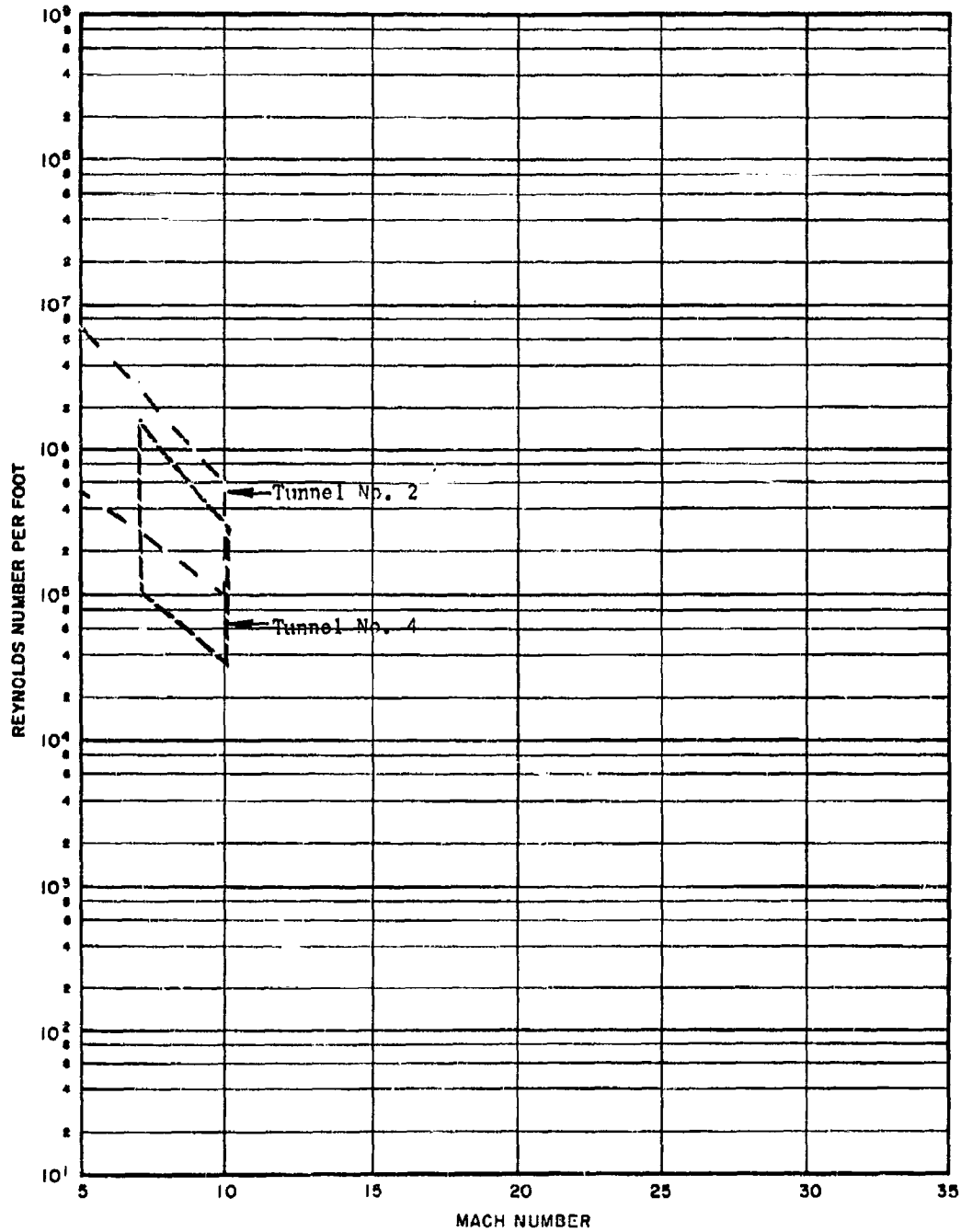
A) Tunnel No. 2 - 30 seconds at M = 7.

B) Tunnel No. 4 - 30 to 120 seconds, with typical run on the order of 90 seconds.

References

1. "National Wind Tunnel Summary", NASA Report, July 1961.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, April 1960.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Tunnel No. 2
Tunnel No. 4
5
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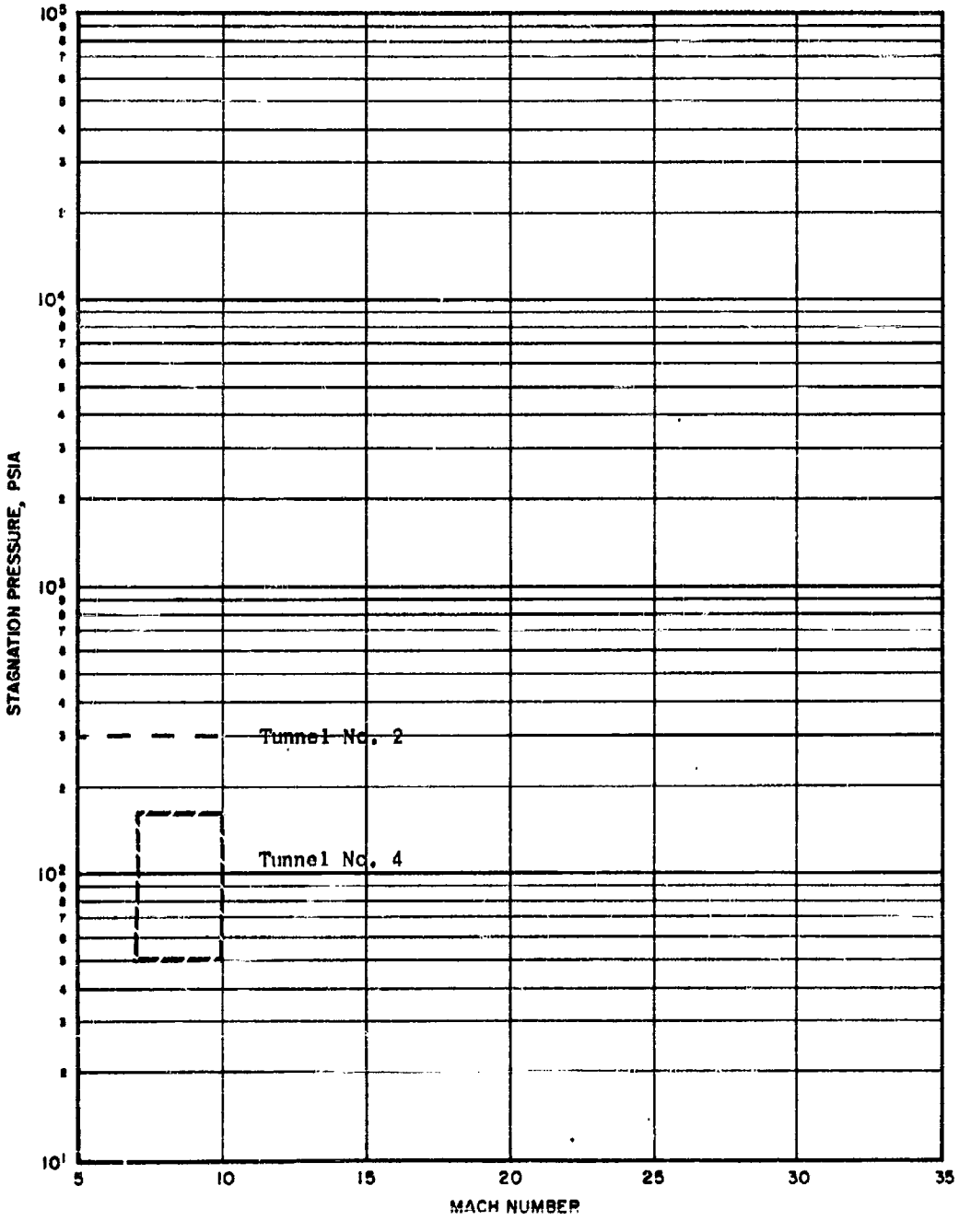
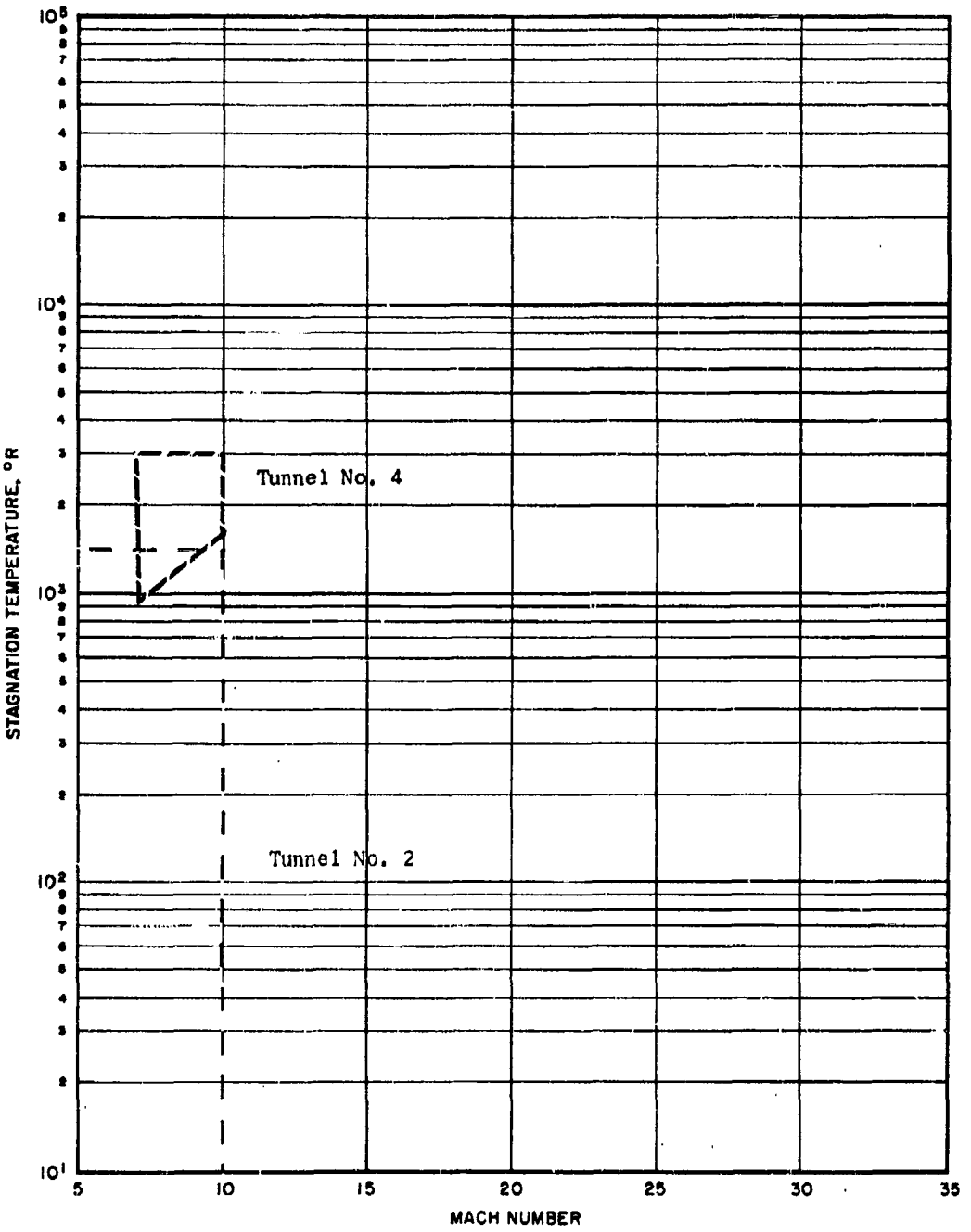
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
Tunnel No. 2
Tunnel No. 4
5
10
15
20
25
30
35


STAGNATION TEMPERATURE, °R
MACH NUMBER
Tunnel No. 4
Tunnel No. 2
5
10
15
20
25
30
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Name of Facility

Sandia Corporation
Sandia Base
Albuquerque, New Mexico

Person Responsible

Mr. K. L. Goin

Type

Two blowdown hypersonic wind tunnels, using pebble bed heaters, are under shakedown and calibration at Sandia.

Nozzle and Test Section

A) At present, the pilot facility has a 5 inch diameter test section, with a conical M = 4 nozzle and a contoured M = 9 nozzle. No other Mach numbers are planned for this facility.

B) The larger tunnel has an 18 inch diameter test section with a contoured M = 7.5 nozzle. Planned nozzles range from M = 4 to M = 11, and an M = 5 nozzle is presently under construction.

Instrumentation and Test Capabilities

Force and pressure tests will be run, with the ability to vary angle of attack during the tests.

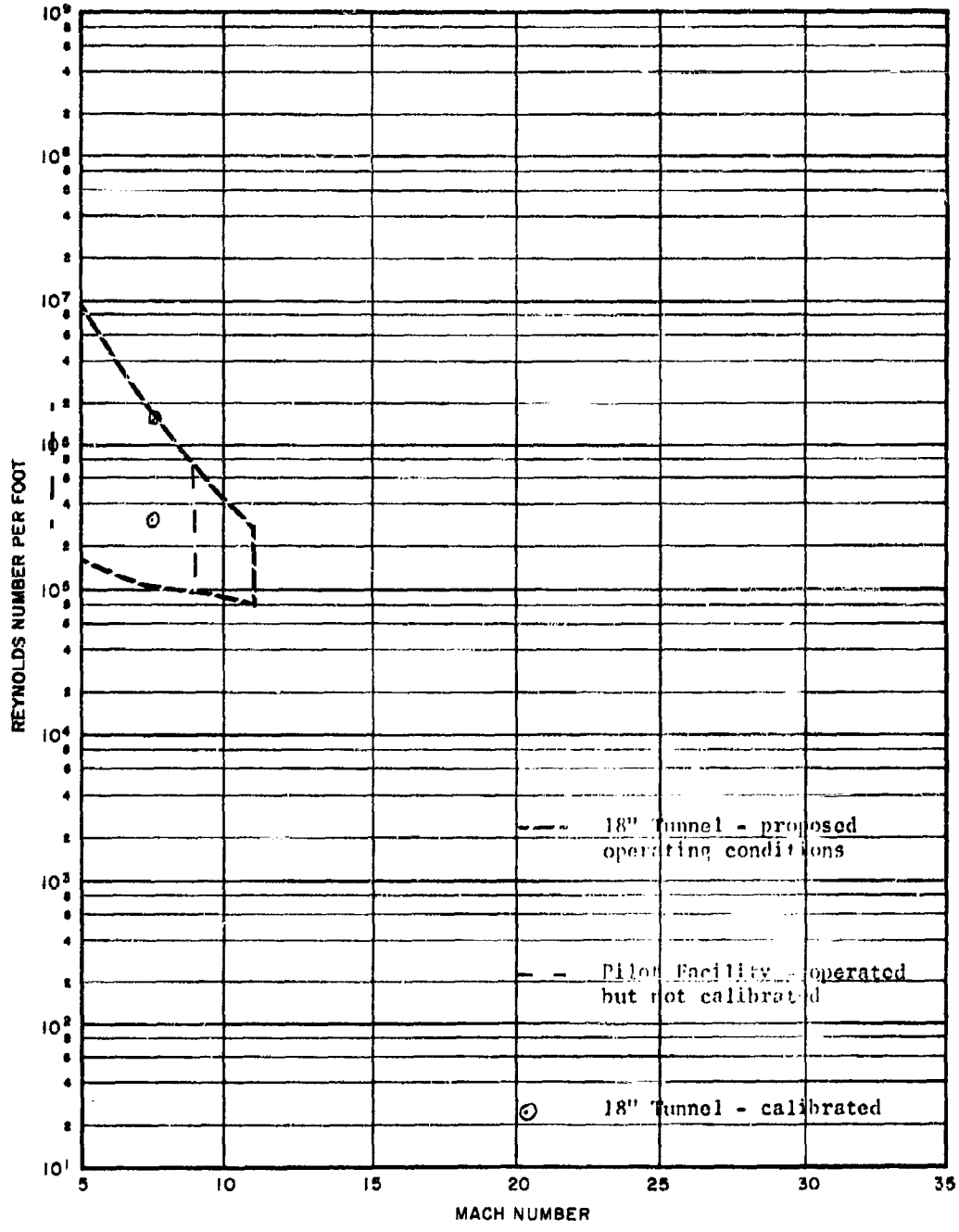
Running Time

Running time is designed for 45 seconds.

References

1. Letter, K. L. Goin to F. A. Vicente, 30 August 1962.

2. Letter, K. L. Goin to F. A. Vicente, 8 January 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
5
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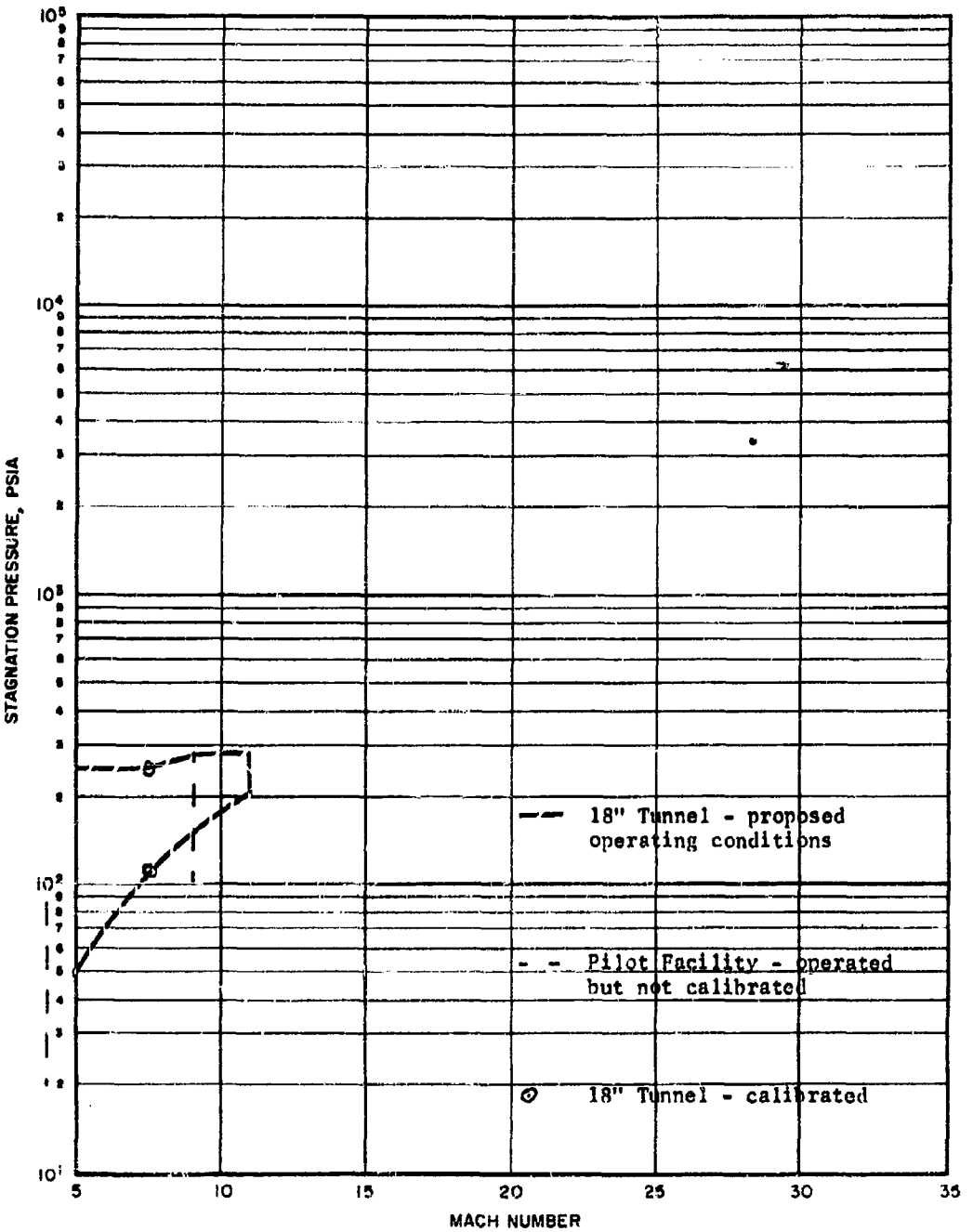
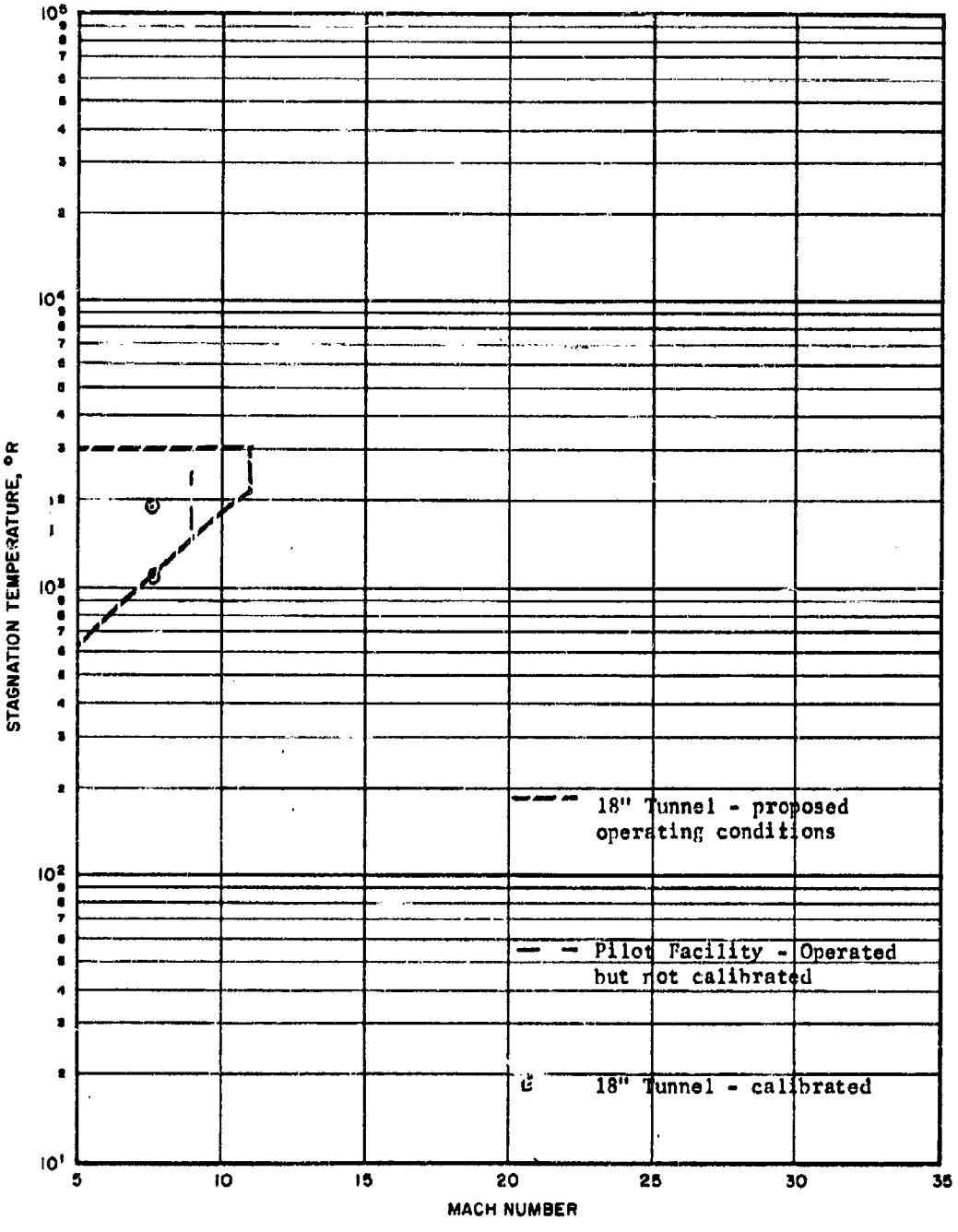
35
18" tunnel - proposed operating conditions
Pilot Facility - operated but not calibrated
18" tunnel - calibrated


STAGNATION PRESSURE, PSIA
MACH NUMBER
18" Tunnel - proposed operating conditions
Pilot Facility - operated but not calibrated
18" Tunnel - calibrated


STAGNATION TEMPERATURE, °R
MACH NUMBER
18" Tunnel - proposed operating conditions
Pilot Facility - Operated but not calibrated
18" Tunnel - calibrated

Name of Facility

Hypersonic Test Facility
Aerodynamics Laboratory
David Taylor Model Basin
Washington 7, D. C.

Person Responsible

Technical Director, Aerodynamics Laboratory

Type

The Hypersonic Test Facility is of the intermittent type.

Nozzle and Test Section

The Hypersonic Test Facility uses axisymmetric nozzles with a Mach number range of approximately 5 to 10. (Nozzles on hand are Mach numbers 4.8, 7.0 and 9.2.) The test core dimensions are 12.1 inches diameter at Mach 5 and 7.2 inches diameter at Mach 10. This facility has a physical test section size of 13.52 inches diameter. Model size is limited to 4 inches diameter with a length of 18 to 24 inches.

Instrumentation and Test Capabilities

This facility has 42 data channels for temperature and pressure and 8 data channels for force. It utilizes digital magnetic tape for processing through Univac I computer, IBM 704 and LARC computer.

Running Time

The maximum running time in the Hypersonic Test Facility is two minutes at Mach 7.

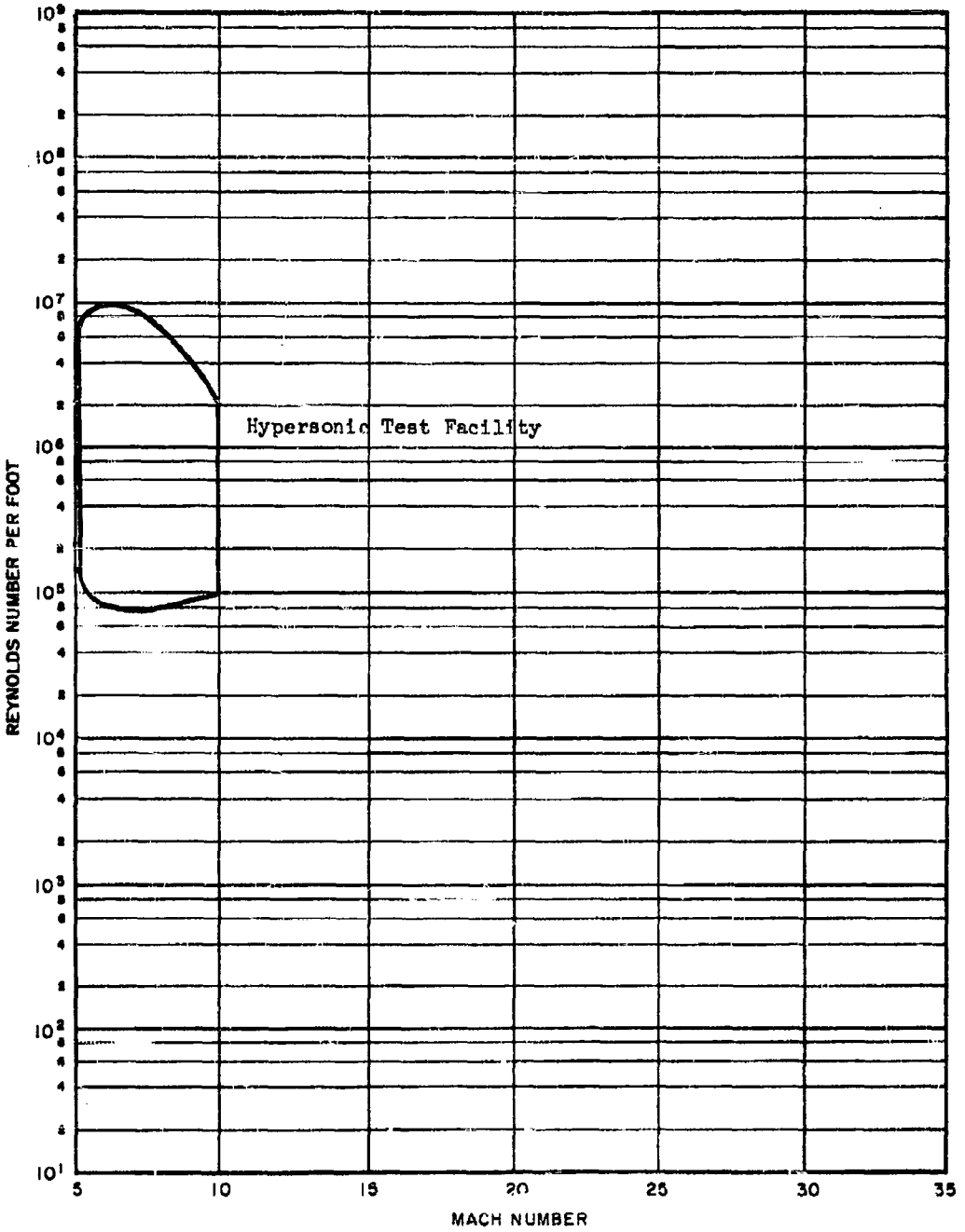
References

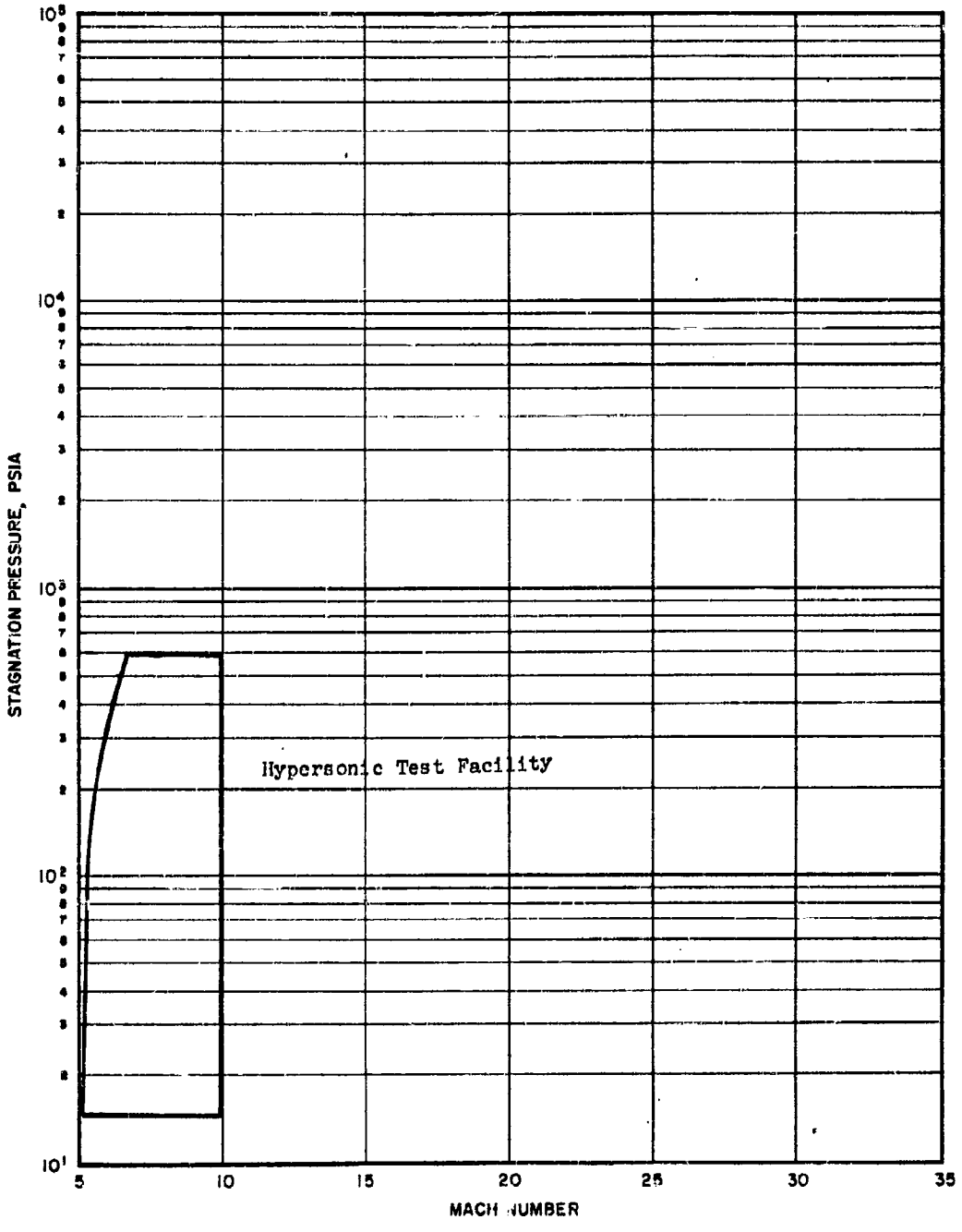
1. "National Wind Tunnel Summary", NASA Report, dated July 1961.

2. "Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, dated April 1960.

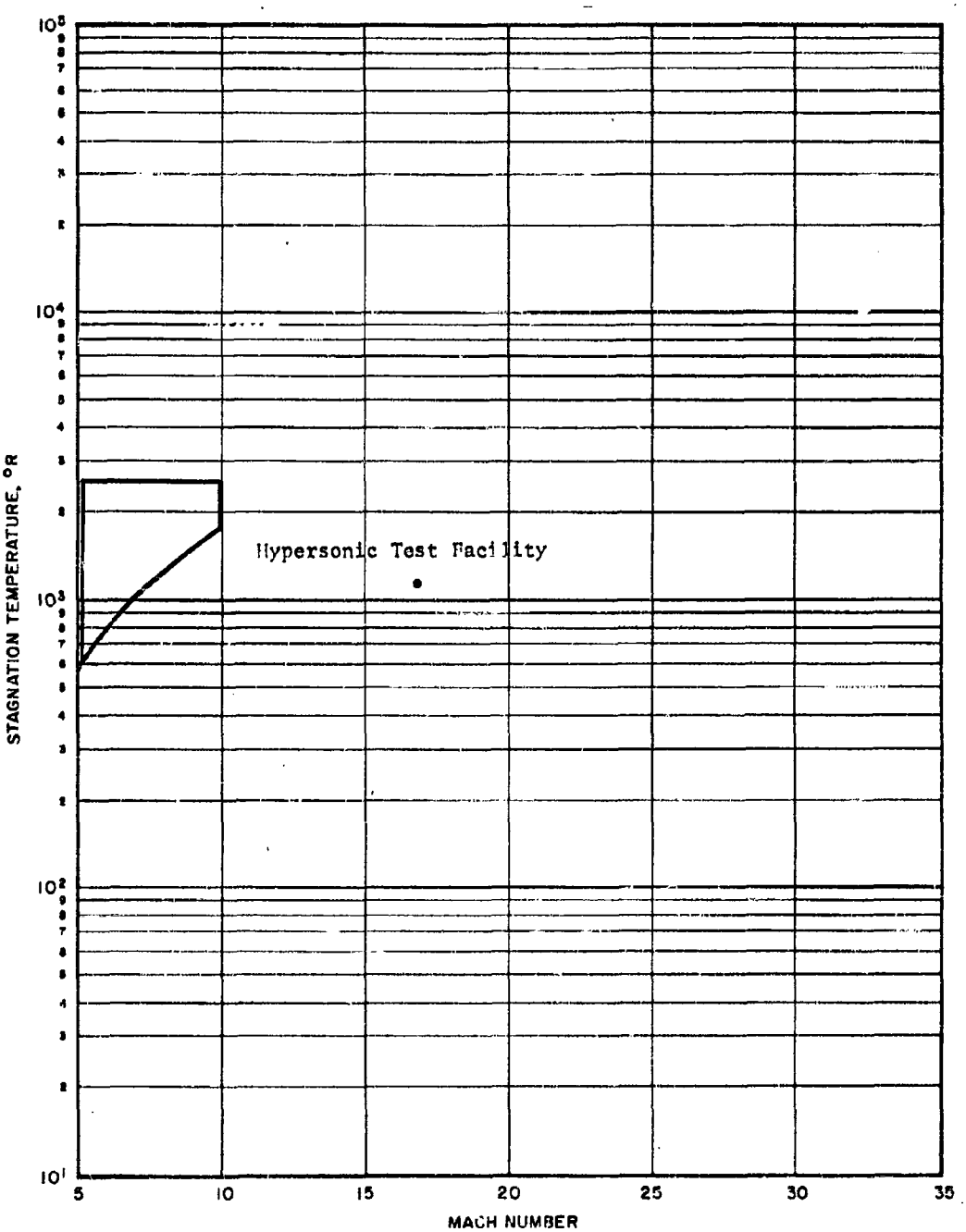
3. Letter, David Taylor Model Basin to N. S. Foy, January 1963.

DAVID TAYLOR MODEL BASIN




STAGNATION PRESSURE, PSIA
MACH NUMBER
Hypersonic Test Facility

DAVID TAYLOR MODEL BASIN



Name of Facility

Research Laboratories
United Aircraft Corporation
East Hartford, Connecticut

Person Responsible

George D. Dickie, Jr., Head, Test Facilities

Type

There are two facilities at United Aircraft which are used for hypersonic research and development. These are:

A) The Hypersonic Wind Tunnel Facility, which is a blowdown tunnel using a pebble bed heater. Continuous operation is also possible.

B) An arc-driven Hotshot, with a 90,000 joule capacitor bank.

Nozzle and Test Section

A) The Hypersonic Wind Tunnel Facility has a two-dimensional wedge nozzle which can be adjusted from M = 4.25 to 10 by adjusting relative positions of the nozzle blocks. The test section is 6 by 6 inches.

B) The Hotshot presently utilizes three conical nozzles, a 45° nozzle with exit diameter of 59.5 inches, an 8° nozzle with 11.5 inch exit diameter and a 23° nozzle with a 27 inch exit diameter.

Instrumentation and Test Capabilities

Force and pressure measurements may be obtained in both facilities. The Hotshot tunnel does not have a force balance as auxiliary equipment.

Running Times

A) The run time for blowdown operation is a minimum of approximately 30 seconds.

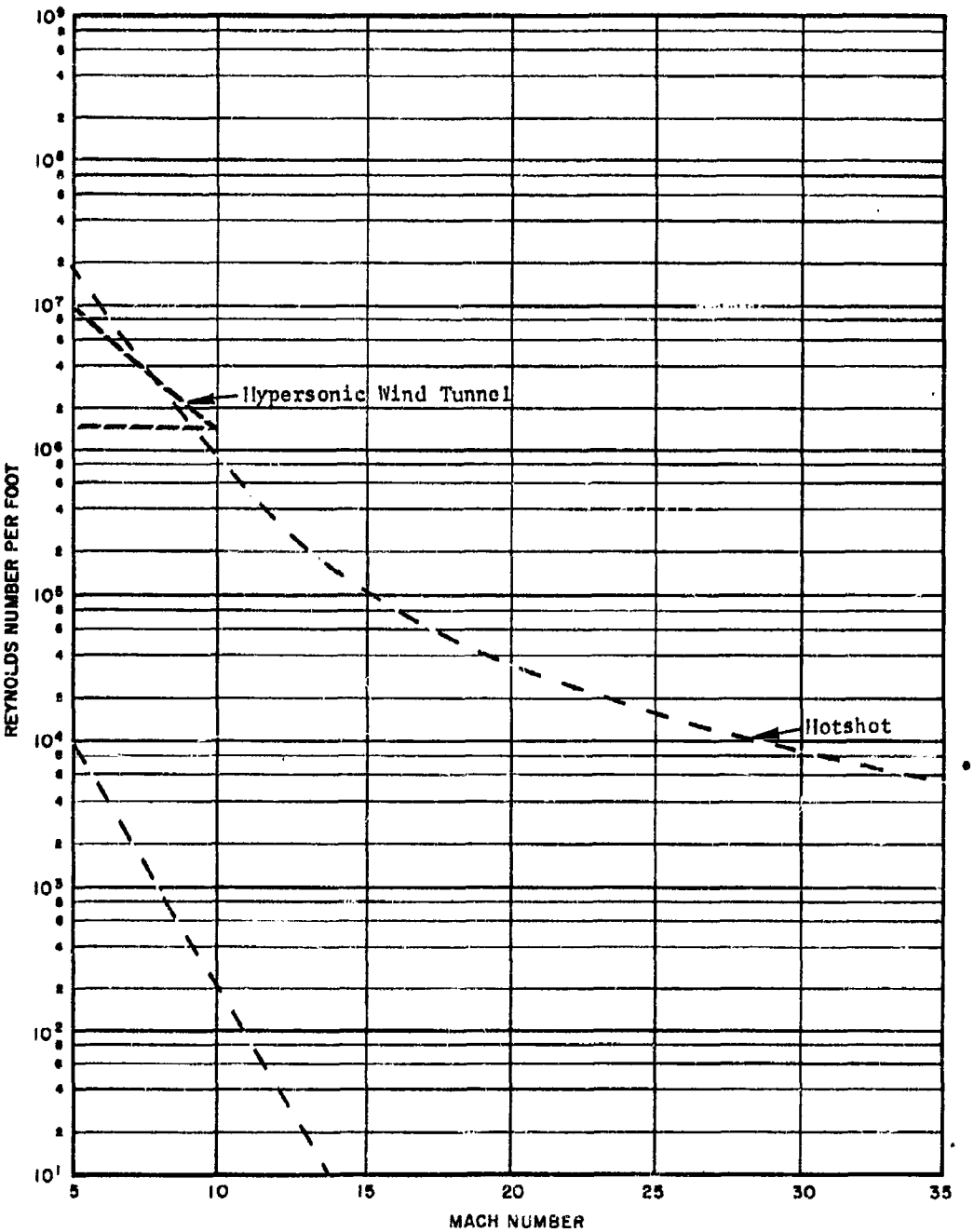
B) The Hotshot presently has running times from .8 to 10 milliseconds.

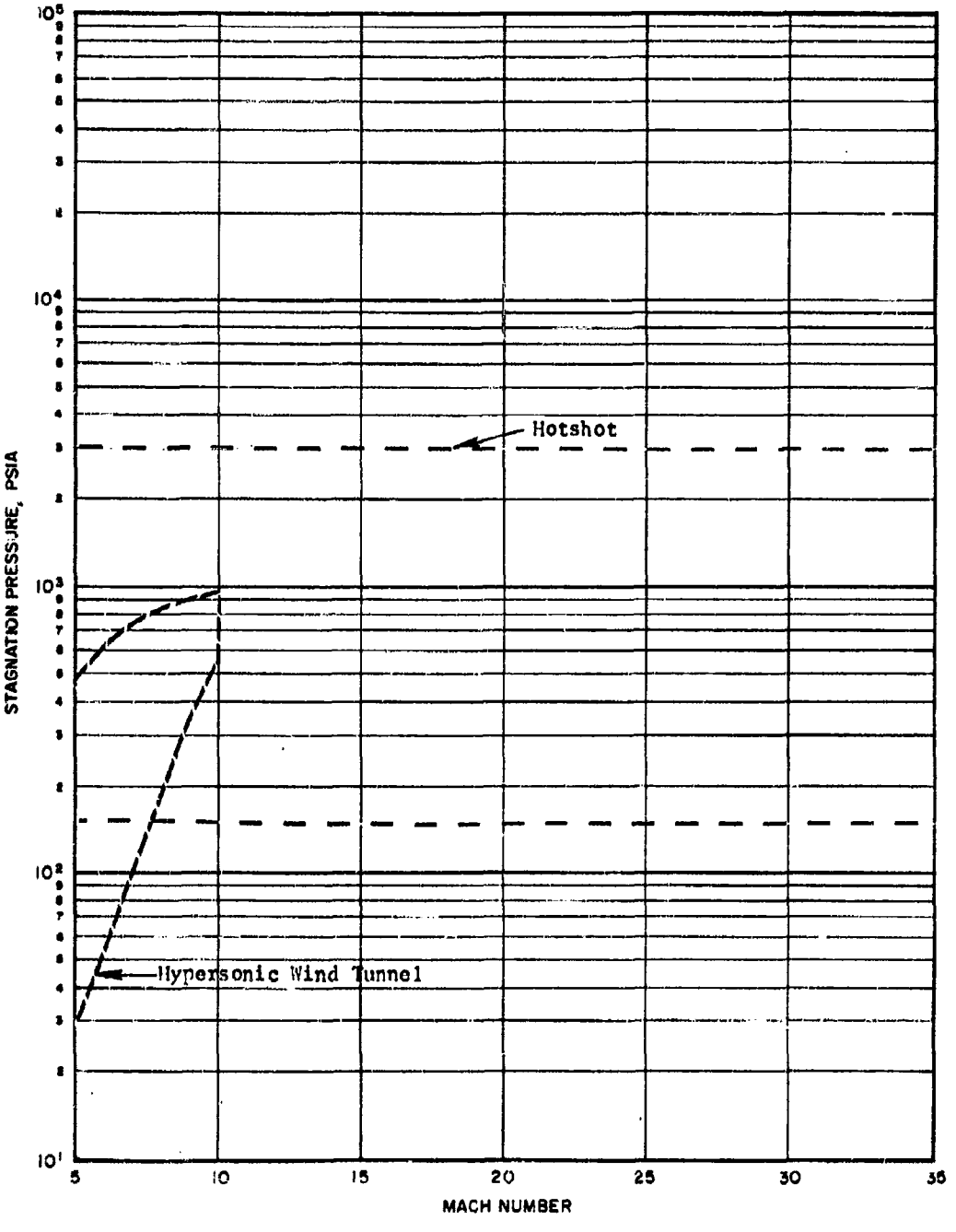
References

1. "Hypersonic Wind Tunnel Facility", United Aircraft Corp. brochure.

2. "UAC Research Laboratories Hot Shot Tunnel", by L. F. Case, 16th Semi-Annual Meeting, Supersonic Tunnel Association.

3. Letter, G. D. Dickie, Jr. to N. S. Foy, dated 16 January 1963.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hypersonic Wind Tunnel
Hotshot
5
10
15
20
25
30
35


STAGNATION PRESSURE, PSIA
MACH NUMBER
Hotshot
Hypersonic Wind Tunnel
5
10
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25
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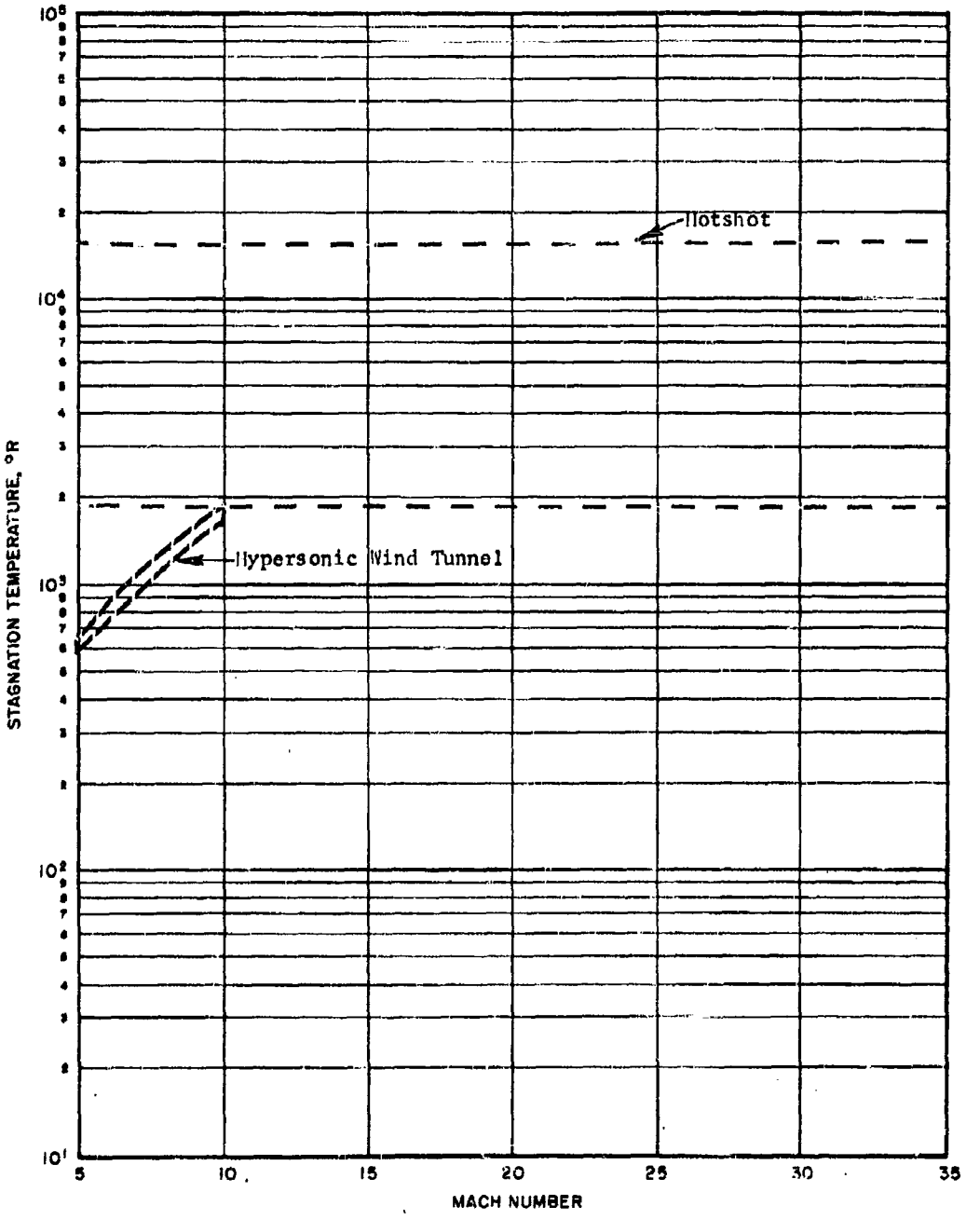
35


Hotshot
Hypersonic Wind Tunnel
STAGNATION TEMPERATURE, °R
MACH NUMBER
5
10
15
20
25
30
35

Name of Facility

Shock Tunnel Facilities
U. S. Naval Ordnance Laboratory
Silver Spring, Maryland

Person Responsible

Mr. S. M. Hastings, Chief, Applied Aerodynamics Division

Type

There are three hypersonic shock tunnels at U.S.N.O.L. These are:

A) 1.5 inch Hypersonic Shock Tunnel No. 1, which is of the free-jet type.

B) 1.5 inch Hypersonic Shock Tunnel No. 2, which is of the cone-nozzle type.

C) 4 inch Hypersonic Shock Tunnel No. 3, which is of the free-jet type.

Nozzle and Test Section

A) Hypersonic Shock Tunnel No. 1 expands from a 1.5 inch diameter barrel into a 6 foot diameter tank. It can accommodate a 3 inch diameter model at M = 8, and an 8 inch diameter model at M = 12. The Mach number range is from 4.7 to 16.

B) Hypersonic Shock Tunnel No. 2 expands from .25 inches diameter to 29 inches diameter, using a conical nozzle, emptying into a 6 foot diameter dump tank. It can accommodate an 8 inch diameter model at M = 12. Total Mach number range is from 4 to 16.

C) Hypersonic Shock Tunnel No. 3 expands from a 4 inch diameter barrel into an 8 foot diameter tank. It can accommodate a 7 inch diameter model at M = 8, and a 20 inch diameter model at M - 14. Total Mach number range is from 5.6 to 16.

Instrumentation and Test Capabilities

A) Hypersonic Shock Tunnel No. 1 is used to measure pressure and temperature distributions.

B) Hypersonic Shock Tunnel No. 2 is used for study of gas flow characteristics, shock wave attenuation, real gas effects, driver gas mixture efficiencies and nozzle designs.

C) Hypersonic Shock Tunnel No. 3 is used to measure pressure and temperature distributions, flow characteristics and real gas effects.

Running Time

A) Hypersonic Shock Tunnel No. 1 - 400 to 1200 microseconds.

B) Hypersonic Shock Tunnel No. 2 - 2 milliseconds.

C) Hypersonic Shock Tunnel No. 3 - 2 to 3 milliseconds.

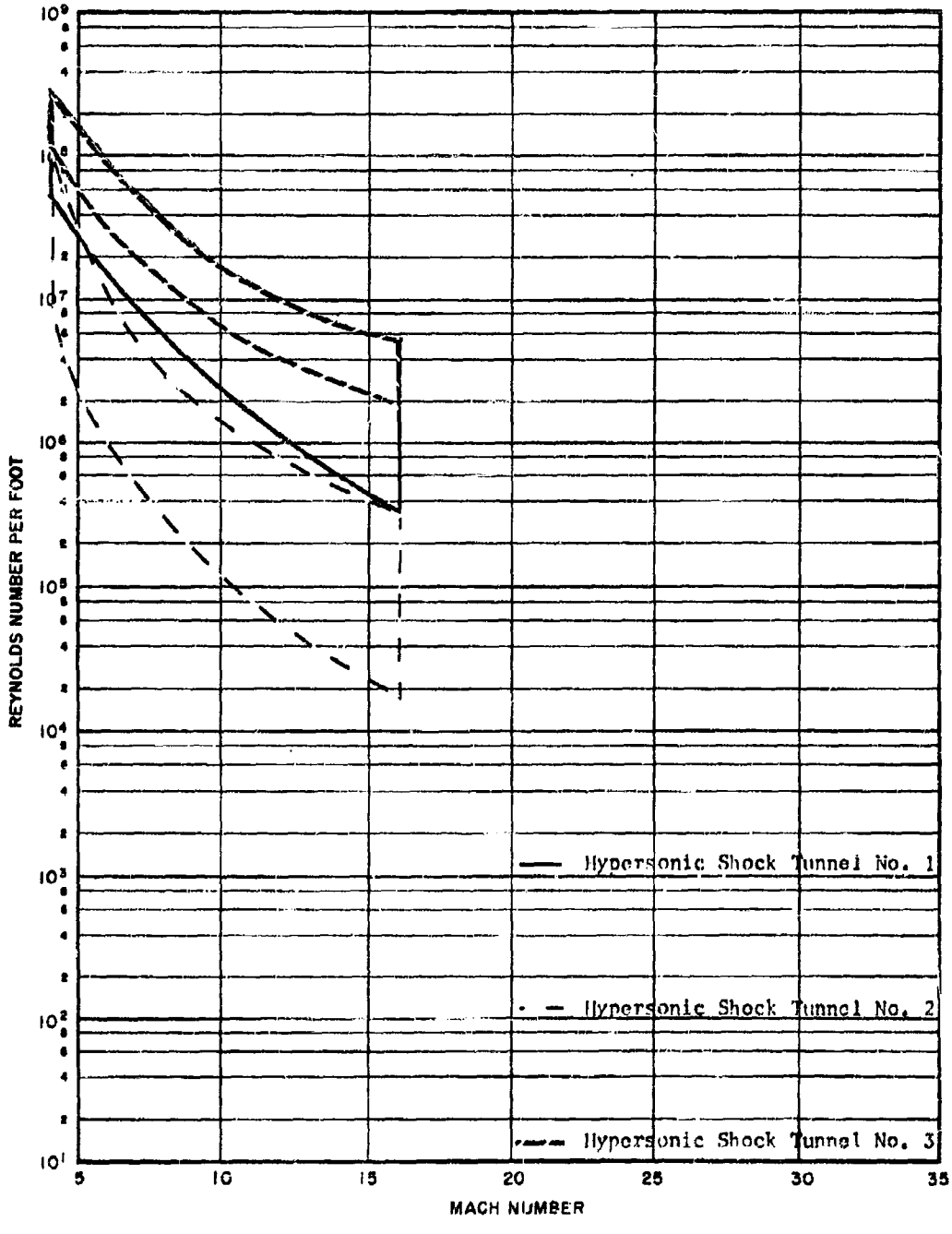
References

1. "Capabilities of the Naval Ordnance Laboratory Aeroballistic Facilities", brochure.

2. Letter, K. R. Enkenhus to F. A. Vicente, 29 August 1962.

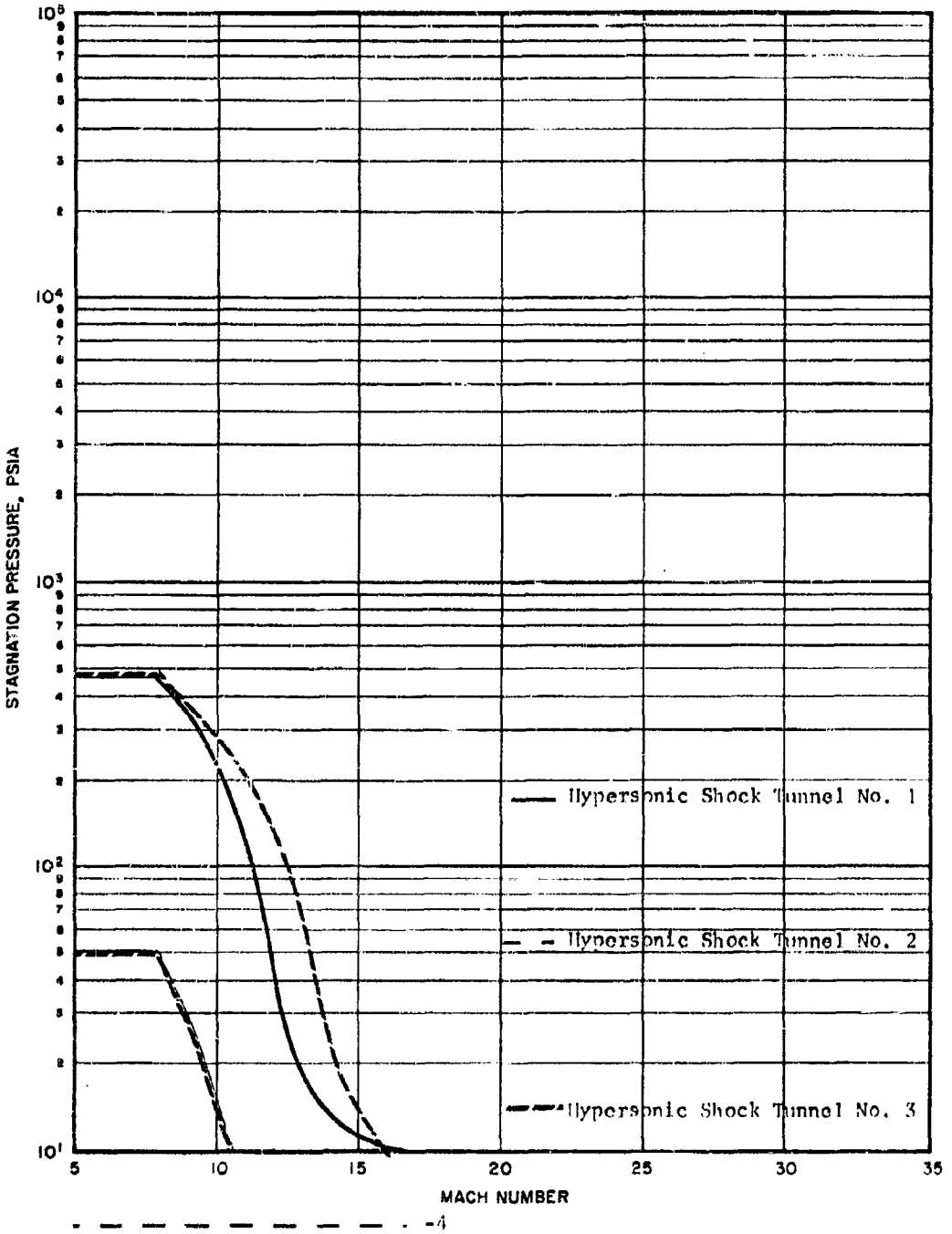
U. S. NAVAL ORDNANCE LABORATORY

Shock Tunnel Facilities



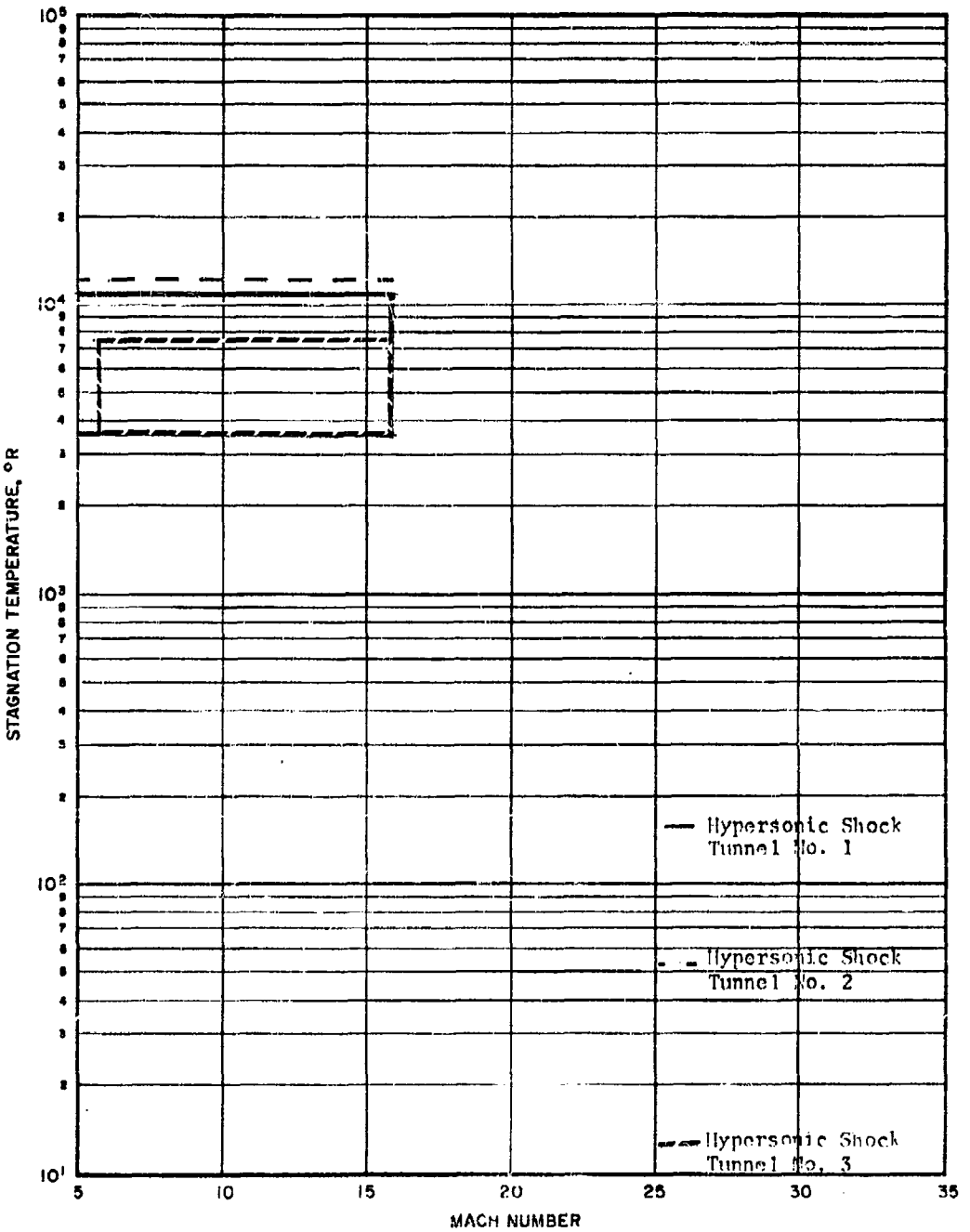
U. S. NAVAL ORDNANCE LABORATORY

Shock Tunnel Facilities



U. S. NAVAL ORDNANCE LABORATORY

Shock Tunnel Facilities



Name of Facility

Wind Tunnel Facilities
U. S. Naval Ordnance Laboratory
Silver Spring, Maryland

Person Responsible

Mr. S. M. Hastings, Chief, Applied Aerodynamics Division

Type

Both Hypersonic Tunnel No. 4 and Hypersonic Tunnel No. 8 are continuous.

Nozzle and Test Section

A) Up to Mach 8, Hypersonic Tunnel No. 4 has a test section 10 inches in diameter. Above Mach 8 the test section has a 12.5 inch diameter. Total Mach number range is 6.8 to 10.

B) Up to Mach 8, Hypersonic Tunnel No. 8 has a test section 18.5 inches in diameter. Above Mach 8 the test section diameter is 24 inches. Total Mach number range is 5 to 10.

Instrumentation and Test Capabilities

A) Tunnel No. 4 has 100 data channels for temperature, 100 to 200 for pressure and 10 for force, with data reduction on an IBM 704. The tunnel is used primarily for viscous flow, heat transfer and friction drag measurements.

B) Tunnel No. 8 has similar data processing techniques, as well as a special purpose computer for force tests. It is used for all types of hypersonic research and development.

Running Time

A) Tunnel No. 4 - 15 minutes to continuous.

B) Tunnel No. 8 - one minute to continuous.

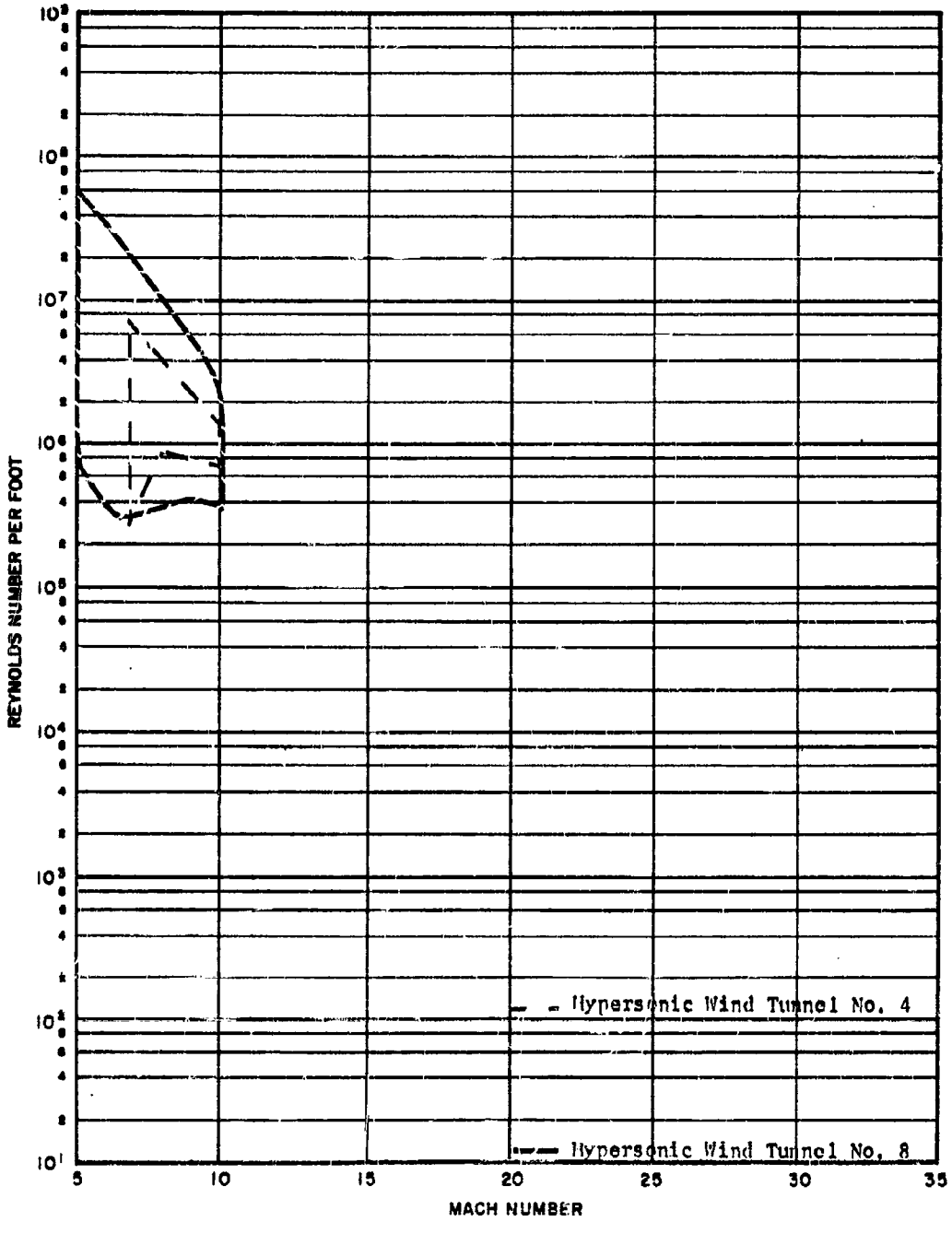
References

1. "Capabilities of the Naval Ordnance Laboratory Aeroballistic Facilities", brochure.

2. Letter, K. R. Enkenhus to F. A. Vicente, dated 29 August 1962.

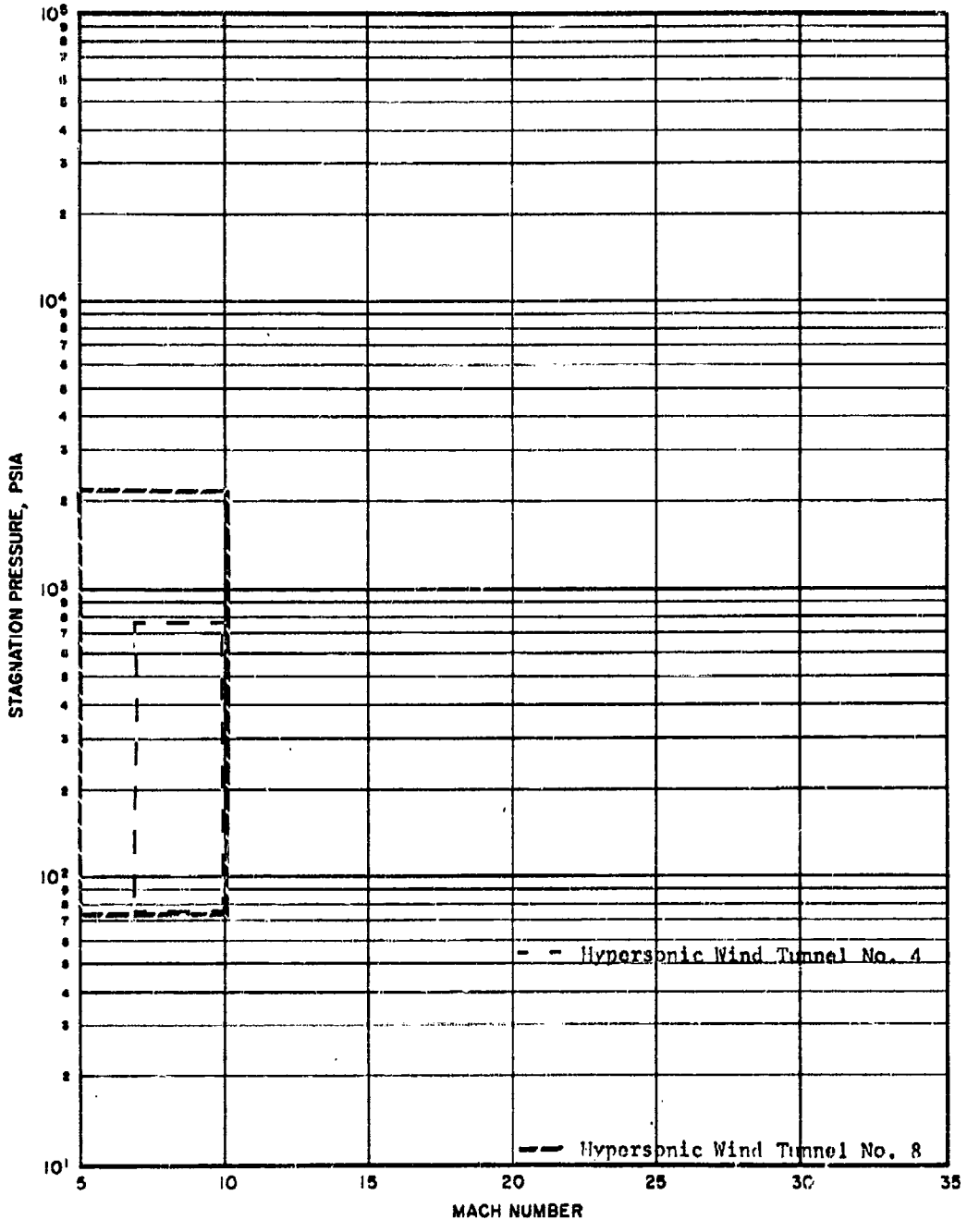
U. S. NAVAL ORDNANCE LABORATORY

Wind Tunnel Facilities



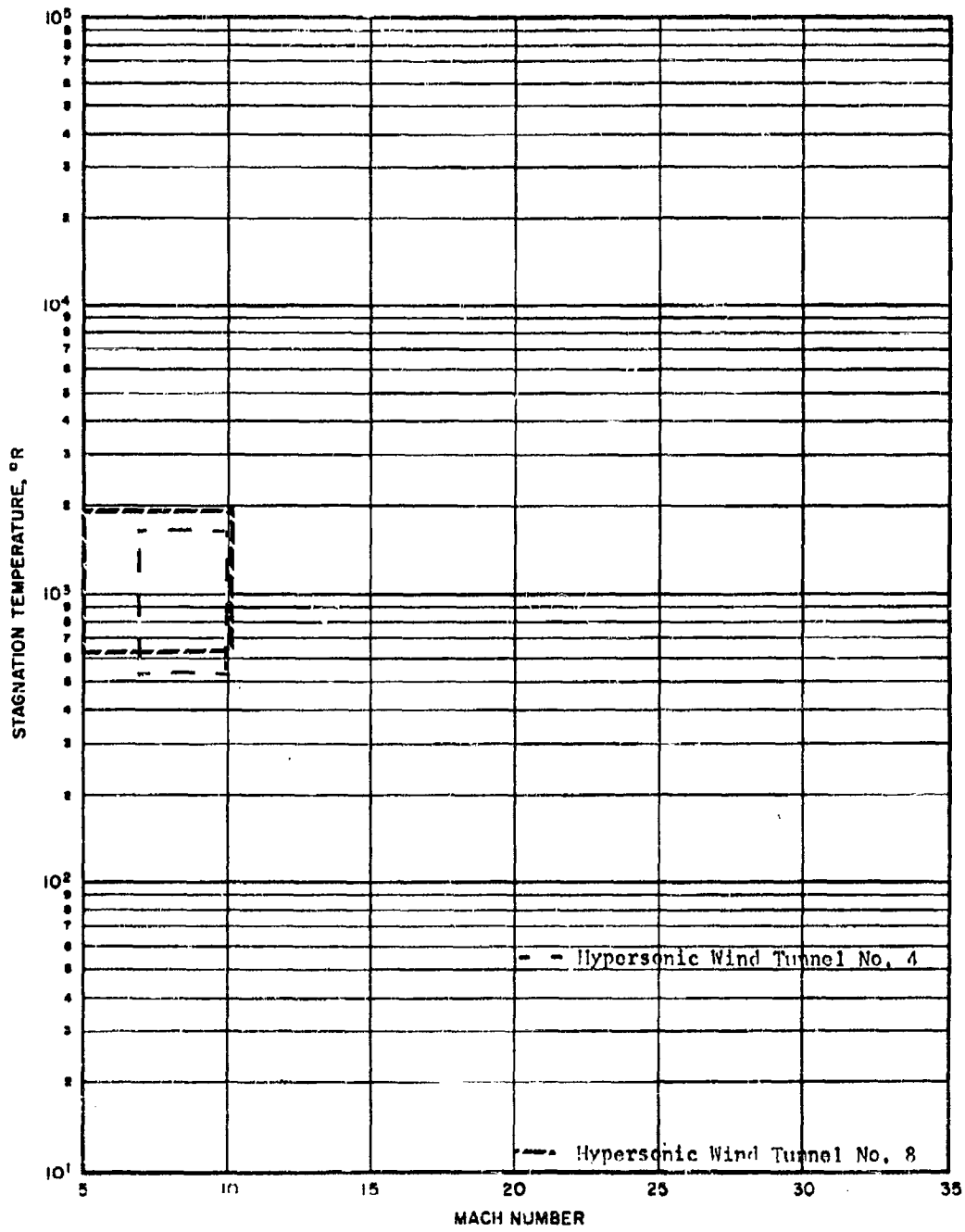
U. S. NAVAL ORDNANCE LABORATORY

Wind Tunnel Facilities



U. S. NAVAL ORDNANCE LABORATORY

Wind Tunnel Facilities



Name of Facility

Hot Shot Tunnel
Aircraft Propulsion Laboratory
The University of Michigan
Ann Arbor, Michigan

Person Responsible

(Mrs.) Pauline M. Sherman, Assistant Professor

Type

The University of Michigan facility is of the hotshot type (inductance).

Nozzle and Test Section

The Hot Shot Tunnel utilizes a 15^{o} total angle axisymmetric conical nozzle with tungsten throat inserts. The conical test section is approximately 19 inches in diameter at the test section centerline.

Instrumentation and Test Capabilities

12 channels of pressure and heat transfer instrumentation are available, as well as Fastax camera equipment. Preliminary operation has been at T_o - 3500^{o}K and P_o - 15,000 psia.

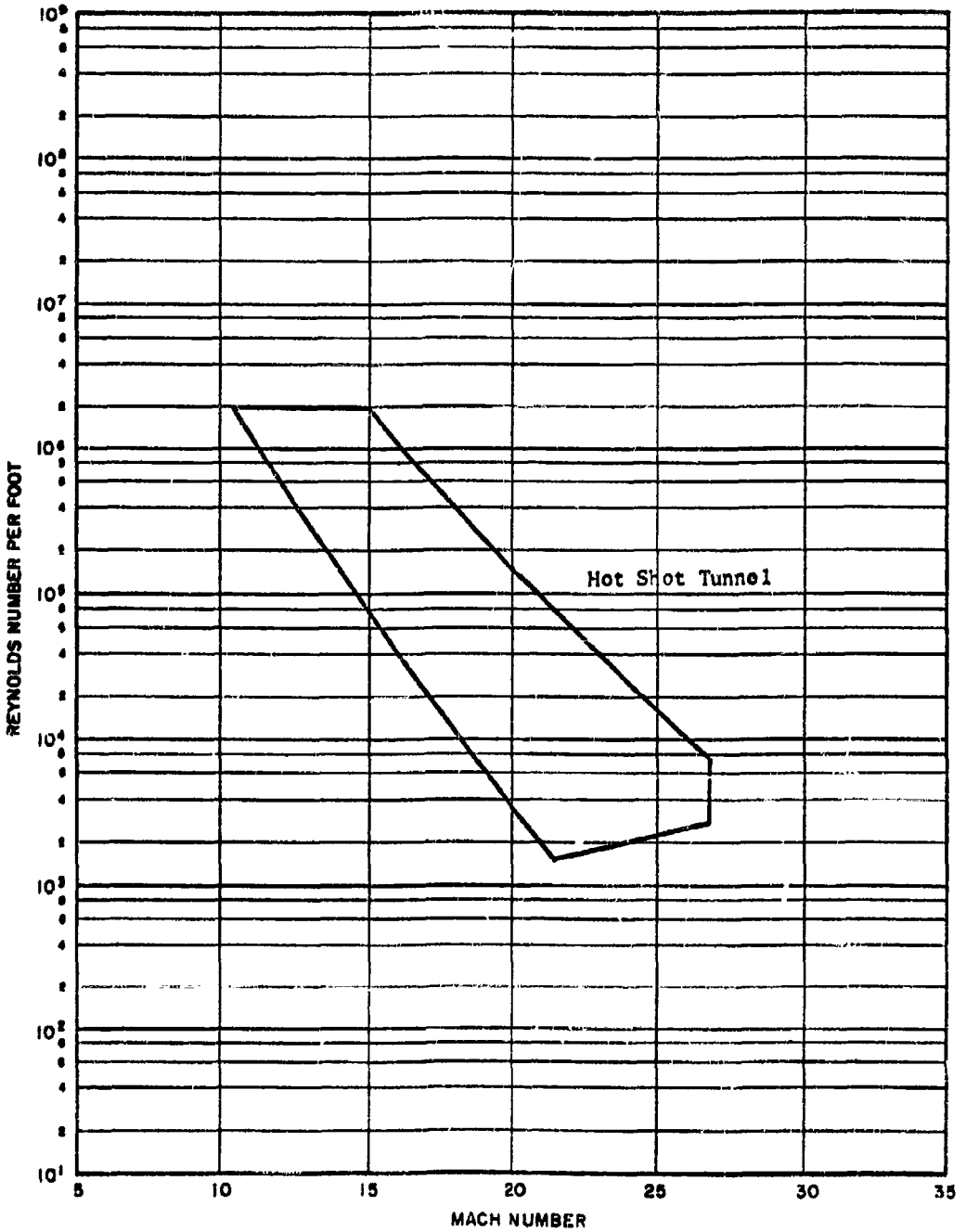
Running Time

The Hot Shot Tunnel has running times on the order of 15 to 20 milliseconds.

References

1. "Design Considerations for Arc Heated Hypersonic Tunnel", University of Michigan Report No. 02953-1-F, July 1960, by P. M. Sherman et. al, ASTIA No. AD-240708.

2. Letter, P. M. Sherman to N. S. Foy, December 1962.


REYNOLDS NUMBER PER FOOT
MACH NUMBER
Hot Shot Tunnel
5
10
15
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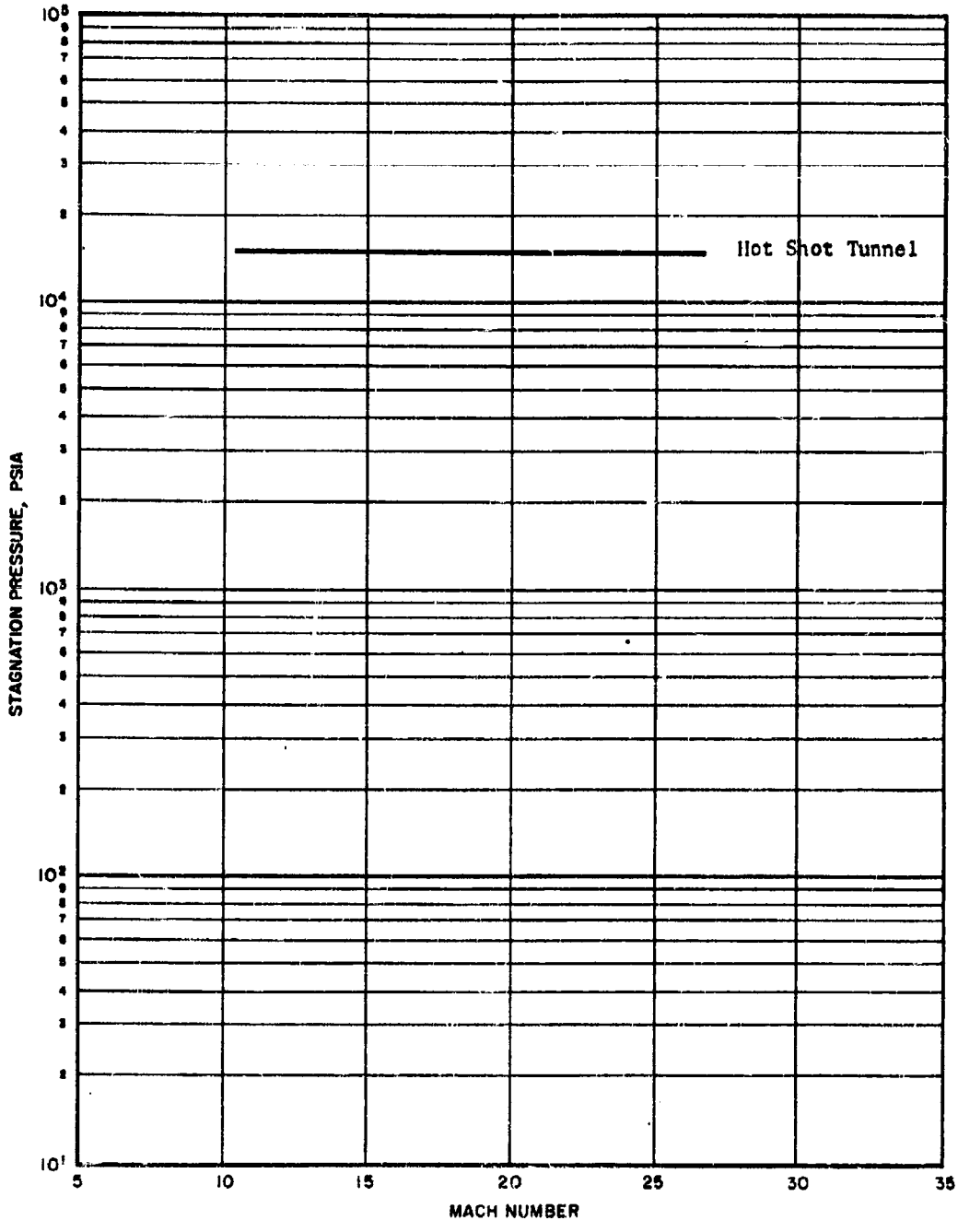
Hot Shot Tunnel
STAGNATION PRESSURE, PSIA
MACH NUMBER
5
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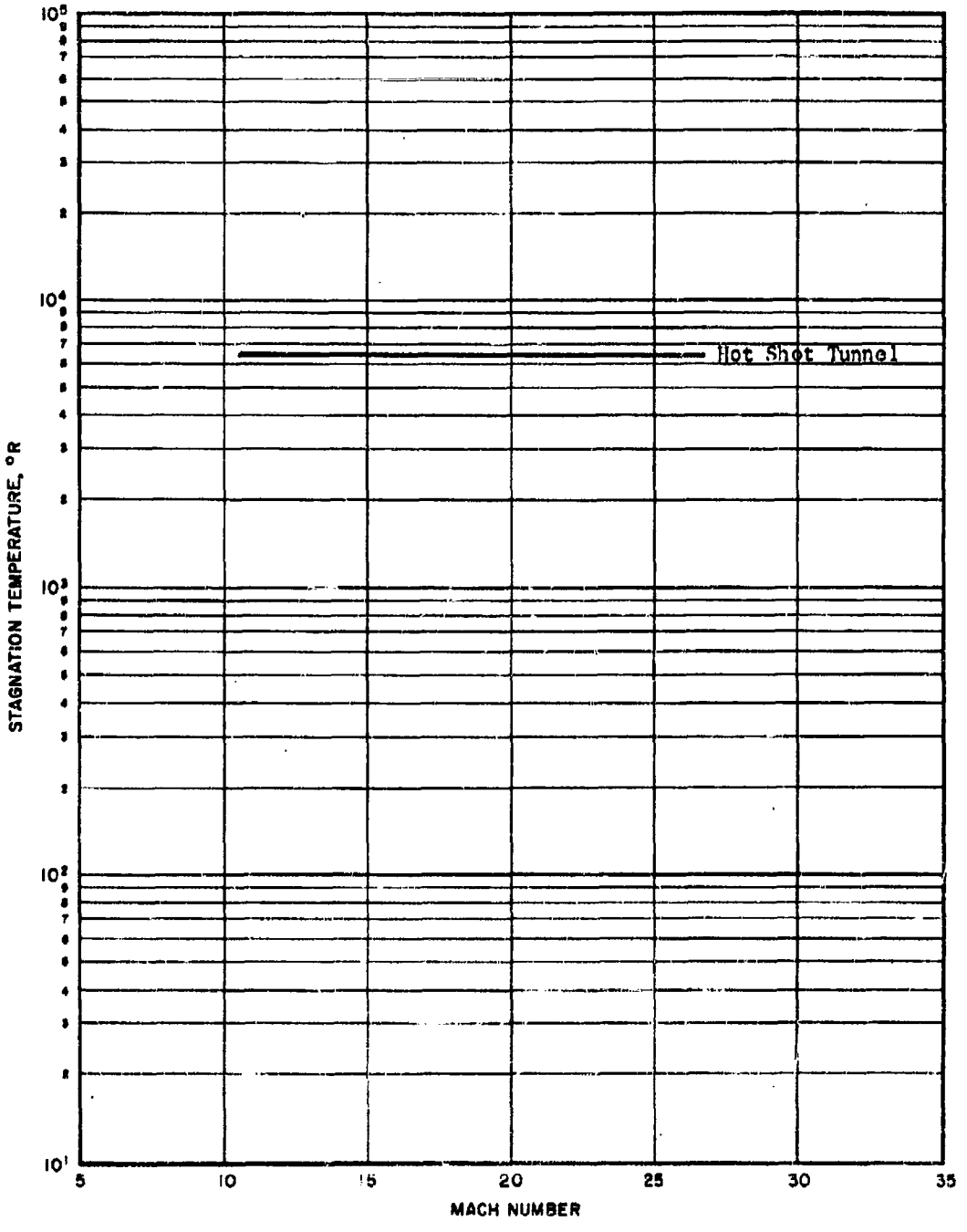
STAGNATION TEMPERATURE, °R
MACH NUMBER
Hot Shot Tunnel
5
10
15
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Name of Facility

Low Density Wind Tunnel
Engineering Center
University of Southern California
935 West 37th Street
Los Angeles 7, California

Person Responsible

Mr. J. G. Everton

Type

The USC facility is a continuous low density wind tunnel, using dry nitrogen as the working fluid. However, any gas may be used except helium, hydrogen or neon.

Nozzle and Test Section

The nozzle used is of the conical free-jet type. Two nozzles are available, M = 8 to 9 and M = 5.25 to 6. The test section is approximately 2.5 inches (10 cm.) in diameter at M = 8, and one inch (2.5 cm) in diameter at M = 6.

Instrumentation and Test Capabilities

Pressure is the parameter currently being measured in the USC facility.

Stagnation Conditions

At M = 8 stagnation pressure is 25 mm mercury (10^{-3} atm.). At M = 6 stagnation pressure is 60 mm mercury. Stagnation temperature is 300°K (540°R).

Running Time

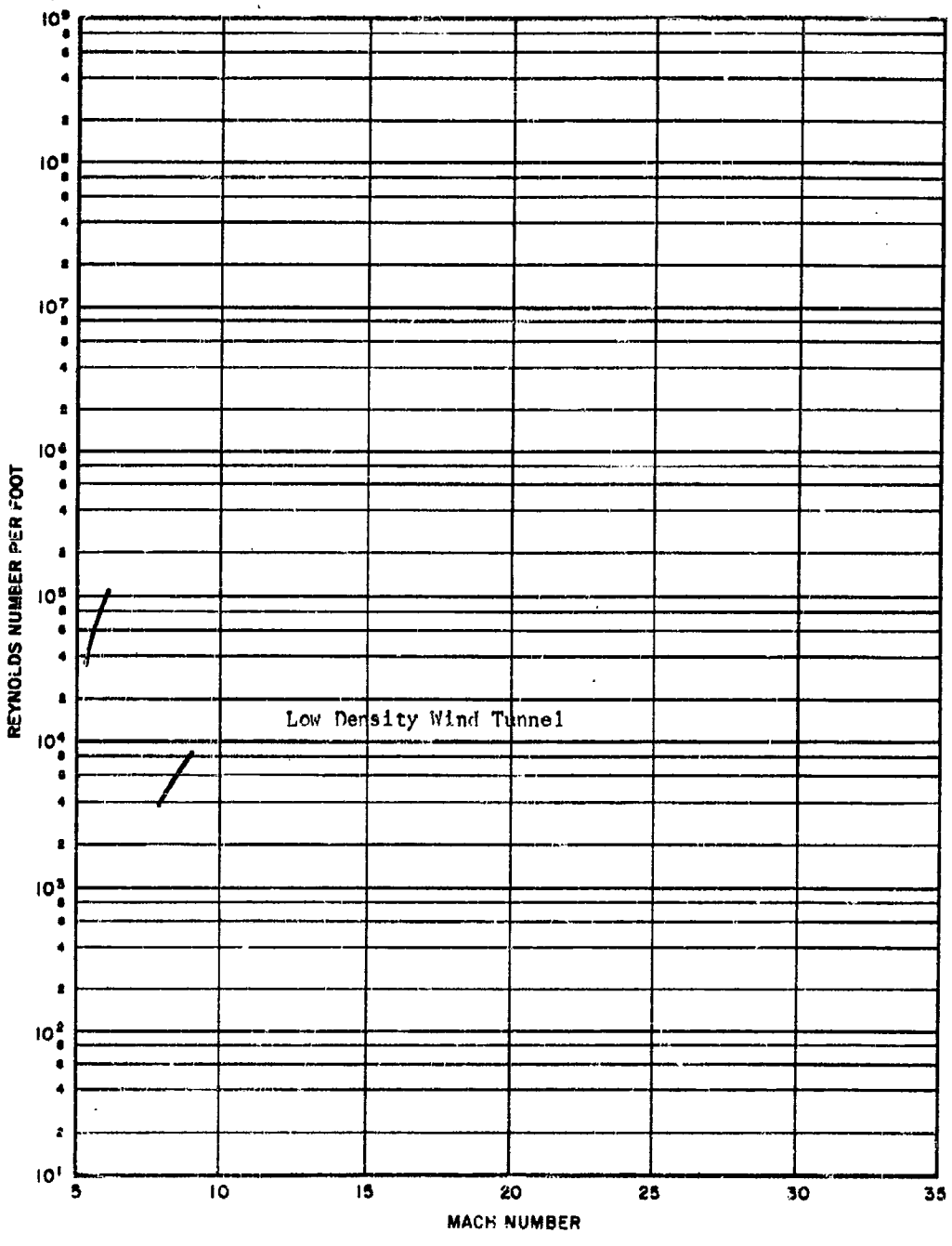
Continuous operation is possible in this facility, with run times of 8 to 10 hours.

References

1. Letter, J. G. Everton to S. T. Chu, 26 June 1962.

2. "A Compilation of Operating Characteristics of Major Hypersonic Wind Tunnels in the United States", Boeing Report No. D2-5785, [illegible].

3. Telephone conversation, [illegible], Everton and N. S. Foy, 17 December 1962.


REYNOLDS NUMBER PER FOOT
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
Low Density Wind Tunnel
5
10
15
20
25
30
35
MACH NUMBER

INDEX TO HYPERSONIC WIND TUNNEL FACILITIES

BY TYPE OF MANAGEMENT AND TYPE OF FACILITY

Section	Government Facilities (continued)	Type
22	NASA-Langley, Other Divisions, Small Facilities	
	12 Inch Hypersonic Ceramic Heated T.	Intermittent
	Hypersonic Aeroelasticity Tunnel	Intermittent
	15 Inch Hypersonic Flow Apparatus	Intermittent
	2 X 2 Foot Low Density Hypersonic T.	Continuous
23	NASA-Langley, Large Hypersonic Facilities	
	Continuous Flow Hypersonic Tunnel	Continuous
	Hyperthermal Leg	Intermittent
	Hypersonic Dynamics Leg	Intermittent
	8 Foot High Temp. Structures Tunnel	Intermittent
24	NASA-Lewis Research Center	
	Mach 7.0 Hypersonic Wind Tunnel	Continuous
35	David Taylor Model Basin	
	Hypersonic Test Facility	Intermittent
37	U. S. Naval Ordnance Laboratory, Shock Tunnel Facilities	
	Hypersonic Shock Tunnel No. 1	Shock Tunnel
	Hypersonic Shock Tunnel No. 2	Shock Tunnel
	Hypersonic Shock Tunnel No. 3	Shock Tunnel
38	U. S. Naval Ordnance Laboratory, Wind Tunnel Facilities	
	Hypersonic Tunnel No. 4	Continuous
	Hypersonic Tunnel No. 8	Continuous
	Industrial Facilities	
6	AVCO Corporation, Research and Development Division	
	300 Atm. Shock Tunnel	Shock Tunnel
8	The Boeing Company	
	44 Inch Hotshot Wind Tunnel	Hotshot
	8 Inch Hotshot Wind Tunnel	Hotshot
	12 Inch Hypersonic Wind Tunnel	Intermittent

Section	Industrial Facilities (continued)	Type
9	Chance-Vought Corporation	
	13 Inch Hypervelocity Tunnel	Hotshot
11	Douglas Aircraft Company	
	Hypersonic Two-Foot Tunnel	Intermittent
	Hypervelocity Impulse Tunnel	Shock Tunnel
12	FluiDyne Engineering Corporation	
	20 Inch Hypersonic Tunnel	Intermittent
13	General Dynamics/Convair	
	Shock Driven Wind Tunnel	Shock Tunnel
14	General Electric/MSVD	
	30 Inch Shock Tunnel	Shock Tunnel
15	Grumman Aircraft Engineering Corporation	
	Hypersonic Shock Tunnel	Shock Tunnel
17	Lockheed Missiles and Space Company	
	3 Inch Shock Tunnel	Shock Tunnel
	Spark Heated Tunnel	Hotshot
18	Martin-Marietta Corporation	
	Hotshot Wind Tunnel	Hotshot
20	McDonnell Aircraft Corporation	
	Hypervelocity Impulse Tunnel	Hotshot
25	North American Aviation, Inc., Los Angeles Division	
	12 Inch Diameter Shock Tunnel	Shock Tunnel
	12 Inch Diameter Hotshot	Hotshot
	17 Inch Diameter Facility	Intermittent
26	North American Aviation, Inc., S. and I.D.	
	Electrodynamics Facility	Hotshot

Section	Industrial Facilities (continued)	Type
27	Northrop Corporation, Norair Division	
	Hypersonic Facility	Intermittent
31	Republic Aviation Corporation	
	Hypersonic Wind Tunnel	Intermittent
	Hypervelocity Wind Tunnel	Shock Tunnel
32	Rhodes and Bloxsom	
	60 Inch Hypervelocity Tunnel	Hotshot
34	Sandia Corporation	
	Pilot Facility	Intermittent
	18 Inch Tunnel	Intermittent
36	United Aircraft Corporation	
	Hypersonic Wind Tunnel Facility	Intermittent cont. operation possible
	Arc-Driven Hotshot	Hotshot
	University and Non-Profit Corporation Facilities	
3	Aerospace Corporation	
	Hypersonic Shock Tunnel	Shock Tunnel
4	Armour Research Foundation	
	Hypersonic Wind Tunnel	Intermittent
10	Cornell Aeronautical Laboratories, Inc.	
	48 Inch Shock Tunnel	Shock Tunnel
	High Energy Shock Tunnel	Shock Tunnel
	Wave Superheater	Intermittent
19	Massachusetts Institute of Technology	
	Gas Dynamics Facility	Continuous
	18 × 24 Inch Wind Tunnel	Continuous

Section	University and Non-Profit Corporation Facilities (continued)	Type
28	Ohio State University	
	12 Inch Hypersonic Wind Tunnel	Continuous
29	Polytechnic Institute of Brooklyn	
	Blowdown Hypersonic Wind Tunnels	Intermittent
	Shock Tunnel	Shock Tunnel
30	Princeton University	
	3 Inch Helium Hypersonic Wind Tunnel	Intermittent
	6 Inch Helium Hypersonic Wind Tunnel	Intermittent
	3 Inch Heated Air Tunnel	Intermittent
	5 Inch Nitrogen Tunnel	Intermittent
33	Rosemount Aeronautical Laboratories	
	Tunnel No. 2	Intermittent
	Tunnel No. 4	Intermittent
39	University of Michigan	
	Hot Shot Tunnel	Hotshot
40	University of Southern California	
	Low Density Wind Tunnel	Continuous

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